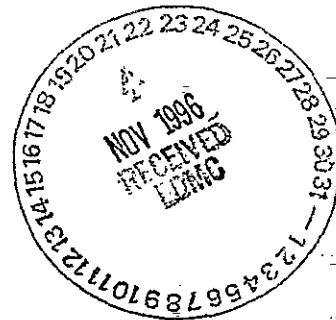
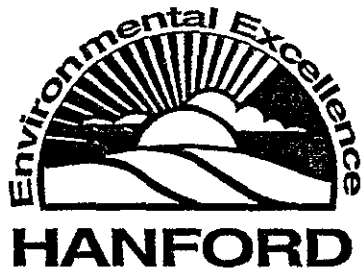


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Rev. 0

Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units



Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Bechtel Hanford, Inc.
Richland, Washington

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Rev. 0

Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units

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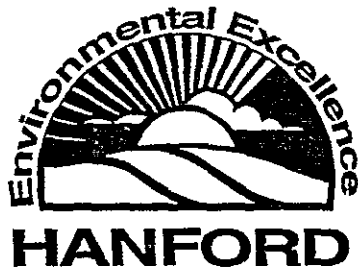
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EXECUTIVE SUMMARY

Introduction

This document presents technical information on groundwater contamination in the 100-BC-5, 100-FR-3, 100-HR-3, and 100-KR-4 groundwater operable units on the Hanford Site. These operable units are defined for groundwater that underlies the retired plutonium production reactors and support facilities located along the Hanford Reach of the Columbia River. An additional 100 Area groundwater operable unit, 100-NR-2, is addressed by separate documentation.

In this document, the most recent site information has been assembled into conceptual site models (CSM). The objective was to assemble and evaluate the best information available to support a better understanding of the nature, extent, and transport of contamination in each groundwater operable unit. These CSMs are recommended for use to assess and prioritize 100 Area groundwater remediation options. As information becomes available this document can easily be updated to reflect new relevant changes in site conditions.

Groundwater is the medium by which contaminants are discharged to the Columbia River—an environment in which human and ecological receptors may be at risk if exposure occurs. The presence of significant levels of chromium in groundwater near the Columbia River has been observed in the 100-HR-3 and 100-KR-4 groundwater operable units. In response, DOE-RL has initiated an interim remedial measure (IRM) in both operable units. The evaluations conducted for this CSM report were used as a basis for the IRM design and will be used in the future to guide performance monitoring. Information generated during IRM operations will also be evaluated as the CSM is updated in the future. Contamination levels and potential risks have not been deemed sufficient to warrant accelerated remediation activities in the 100-BC-5 and 100-FR-3 groundwater operable units.

100 Area Contaminant Hydrogeology

The CSM includes a detailed evaluation of contaminant hydrogeology including the following topics:

- Regional Groundwater Contamination
- Sources for Groundwater Contamination
- Geologic Characteristics of the Contaminated Aquifer
- Groundwater and Columbia River Interaction
- Interpretation of Water Quality Near the Columbia River

The current distribution of principal groundwater contaminants in the 100 Area is shown in Figure ES-1.

Operable Unit-Specific Evaluations

The evaluation for each operable unit was focussed on the contaminants of concern as indicated in each respective limited field investigation (LFI) document. Summaries of the operable unit-specific approach are described below:

100-BC-5 Groundwater Operable Unit. Contaminants of potential concern identified during the LFI are carbon-14, strontium-90, technetium-99, and tritium (which pose a human health risk), and aluminum, chromium, iron, and nickel (which pose an ecological risk). With respect to human health, strontium-90 and tritium remain elevated, while carbon-14 and technetium-99 have dropped below the EPA's standards for maximum contaminant levels (MCL). With respect to the ecological receptors, chromium and iron for filtered samples remain elevated, while nickel has fallen below MCL standards. No new contaminants of potential concern were identified.

100-FR-3 Groundwater Operable Unit: Contaminants of potential concern that were identified during the LFI are arsenic, chromium, manganese, nitrate, strontium-90, and tritium (which pose

a human health risk), and chromium, copper, and lead (which pose an ecological risk). With respect to human health, chromium, manganese, nitrate, strontium-90, and tritium remain elevated while arsenic has dropped below MCL standards. For the ecological list, chromium filtered samples remains elevated while copper and lead have fallen below MCL standards. Trichloroethene (TCE) remains above MCL standards in two wells. No new contaminants of potential concern are identified.

100-HR-3 Groundwater Operable Unit: The 100-HR-3 Operable Unit extends across the prominent bend in the Columbia River channel, which is referred to as the "horn" of the river. The operable unit includes two reactor areas, 100-D/DR and 100-H, along with the 600 Area in between.

- 100-HR-3 (D/DR) Groundwater Operable Unit: Contaminants of potential concern identified during the LFI are chromium, nitrate, strontium-90, and tritium (which pose a human health risk), and chromium and sulfide (which pose an ecological risk). For the human health list, chromium, nitrate, strontium-90, and tritium remain elevated above MCL standards in at least one well. For the ecological list, chromium remains elevated, while sulfide has fallen below standards. Additional constituents elevated above MCL standards are aluminum, iron, manganese, and possibly lead. None of the additional constituents is considered a contaminant of potential concern.
- 100-HR-3 (H) Groundwater Operable Unit: Contaminants of potential concern identified during the LFI are americium-241, carbon-14, chromium, chloroform, nitrate, strontium-90, technetium-99, tritium, and uranium (which pose a human health risk), and chromium and sulfide (which poses an ecological risk). For the human health list, chromium, nitrate, strontium-90, and technetium-99 remain elevated above MCL standards in at least one well. Americium-241, carbon-14, and chloroform were dropped from the suite of analyses used during the LFI because of nondetection. With respect to the ecological list, chromium remains elevated while sulfide has fallen below standards.

100-KR-4 Groundwater Operable Unit. Contaminants of potential concern identified during the LFI are arsenic, carbon-14, chromium, nitrate, and tritium (which pose a human health risk), and chromium, carbon-14, iron, lead, silver, and zinc (which pose an ecological risk). For the human health list, carbon-14, chromium, nitrate, and tritium remain elevated above MCL standards, while arsenic has dropped below standards. For the ecological list, chromium, carbon-14, and iron remain elevated, while lead, silver, and zinc have fallen below standards. Chromium is the target of an interim remedial measure involving a pump-and-treat system.

Other constituents that exceed MCL standards are aluminum, manganese, nickel, selenium, strontium-90, gross beta, and trichloroethene. Strontium-90 is considered the only new contaminant of potential concern in the 100-K Area (i.e., not directly called out in LFI document). Strontium-90 is significantly elevated in a well installed in 1994 near a tile field that received effluent from the 100-K East Fuel Storage Basin. The well is not categorized as a "near-river" well.

Groundwater Contamination in the 100 Areas

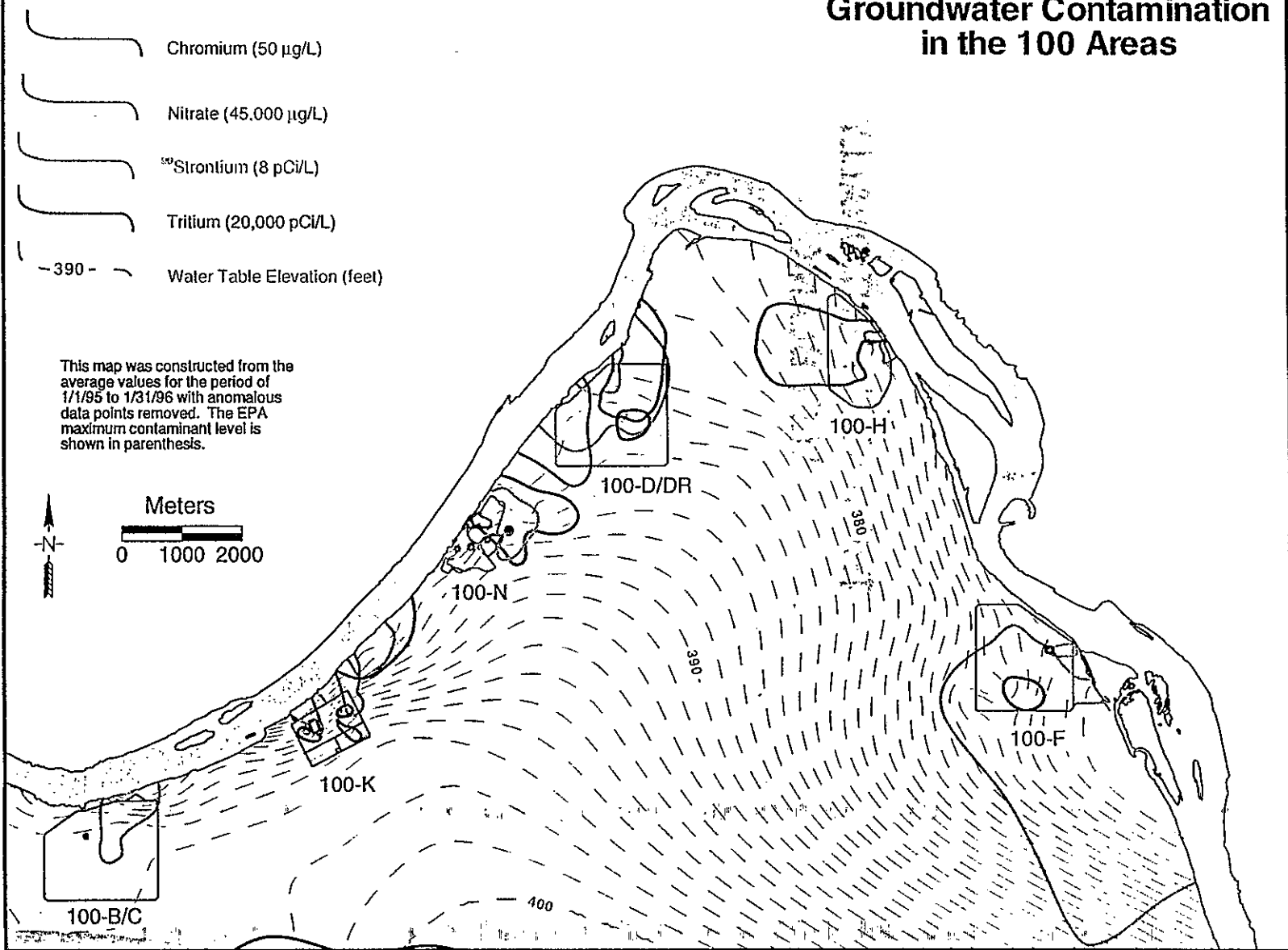


Figure ES-1. Groundwater Contamination in the 100 Area, Hanford Site

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ACRONYMS

AWQC	ambient water quality criteria
CSM	conceptual site model
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study
HEIS	Hanford Environmental Information System
ICP	inductively coupled plasma
IRM	interim remedial measure
LFI	limited field investigation
NGVD	National Geodetic Vertical Datum
MCL	maximum contaminant levels
RD/RA	remedial design/remedial action
RI/FS	remedial investigation/feasibility study
TCE	trichloroethene
TSD	treatment, storage, and disposal
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

This document presents technical information on groundwater contamination in the 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units on the Hanford Site. These operable units are defined for groundwater that underlies the retired plutonium production reactors and their associated support facilities. The reactor areas are located along the Columbia River in the northern portion of the Hanford Site (Figure 1-1). Collectively, the retired reactor areas and the adjacent undeveloped areas are referred to as the "100 Area." The technical information presented in this document supports a conceptual site model (CSM) for each operable unit. An additional reactor area operable unit, 100-NR-2, is addressed under separate documentation (Borghese et al., 1996).

1.1 CONCEPTUAL SITE MODELS

As described by the U.S. Environmental Protection Agency (EPA), a CSM is developed to evaluate potential risks to human health and the environment from contamination (EPA, 1988). A CSM was initially developed for each 100 Area operable unit using information that was available during the scoping phase of the remedial investigation. The CSMs are included in work plans for each operable unit. Figure 1-2 illustrates contaminant exposure pathways, a key aspect of the CSM, which was prepared for the 100-HR-3 Operable Unit work plan (DOE-RL, 1992a).

According to EPA guidance, "The conceptual site model should include known and suspected sources of contamination, types of contaminants and affected media, known and potential routes of migration, and known or potential human and environmental receptors" (EPA, 1988). This implies that a substantial data base of technical information should be assembled during the remedial investigation. As new information becomes available during site characterization activities and interim remedial measures, the CSM is refined.

Contaminant transport by groundwater flow is a principal aspect of CSMs for the retired reactor areas. Groundwater flow is the mechanism by which contaminants are dispersed into the Columbia River, an environment in which human and ecological receptors may be at risk if exposure occurs.

1.2 ROLE OF A CONCEPTUAL SITE MODEL IN REMEDIATION

Maintaining a conceptual model for groundwater contamination is essential during the remedial investigation/feasibility study (RI/FS) process. The CSM provides a description of the contaminant, its geographic extent, the pathways by which it disperses, and the potential receptors that are at risk. When the risk and methods to reduce it are readily apparent,

accelerated remediation efforts are started to reduce the contamination problem and to generate additional information on which to base selection of a final remediation alternative (Thompson, 1991).

The presence of chromium in groundwater near the Columbia River indicates the potential for ecological receptor exposure to contamination in the 100-HR-3 and 100-KR-4 Operable Units (DOE-RL, 1995a and 1995b). An interim remedial measure (IRM) to address chromium in groundwater in those operable units is proceeding, and the CSM provides key information for design and performance evaluation applications. The information and its applications include the following:

- Chromium concentrations representative of current conditions. Plume maps provide system designers with the geographic limits for groundwater extraction and injection well networks. Concentration data are used in designing the treatment methodology.
- Geologic framework through which contaminants move. This information provides ranges for various design parameters for extraction and injection wells, such as the length of open intervals in well casings and depth settings for pump intakes. Numerical simulation of contaminant movement requires a description of the geometry of the natural system. The reliability of estimates and predictions made by numerical modeling is closely tied to the degree of certainty associated with the CSM.
- Interaction between groundwater and river water. An understanding of the processes occurring at the interface where these two water types meet is useful in siting new extraction wells, defining pumping schedules, devising a performance monitoring system, and developing compliance monitoring criteria.

As the IRM proceeds, the CSM is further refined by data collected to measure the performance of the remediation system. Concurrently, characterization activities proceed within the operable unit to address additional contamination issues. New data for refining CSMs are also obtained from monitoring facility operations and source remediation activities.

For the 100-BC-5 and 100-FR-3 Operable Units, contamination levels do not warrant IRMs. Refinement of the current CSMs occurs periodically as source remediation activities proceed and routine groundwater monitoring is conducted. Selection of final remediation alternatives is expected to occur after completion of source remediation activities.

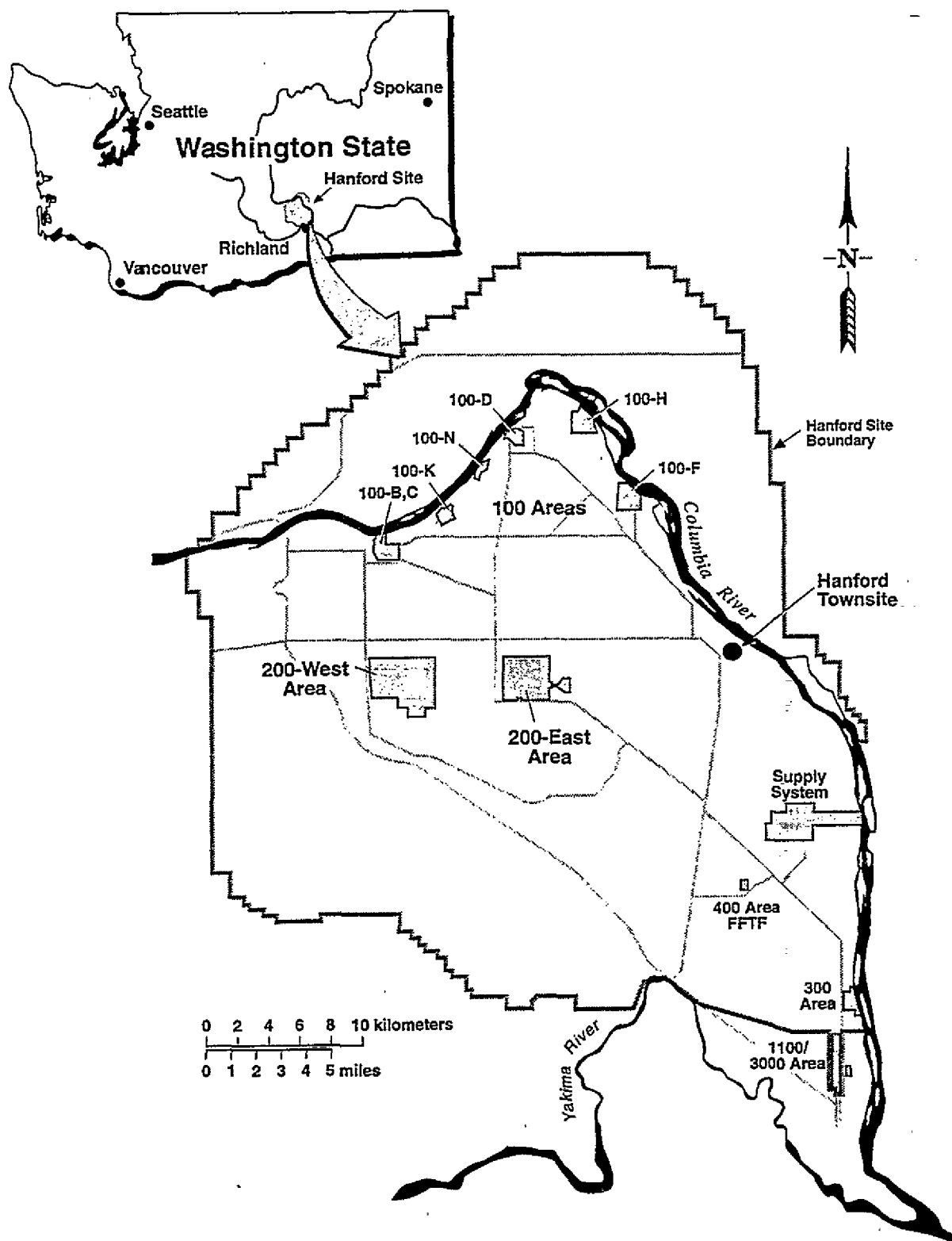
The goal of maintaining CSMs during the RI/FS is to ensure that the understanding of contamination issues in each groundwater operable unit is available to support selection of a final remediation alternative and development of a record of decision.

1.3 ORGANIZATION

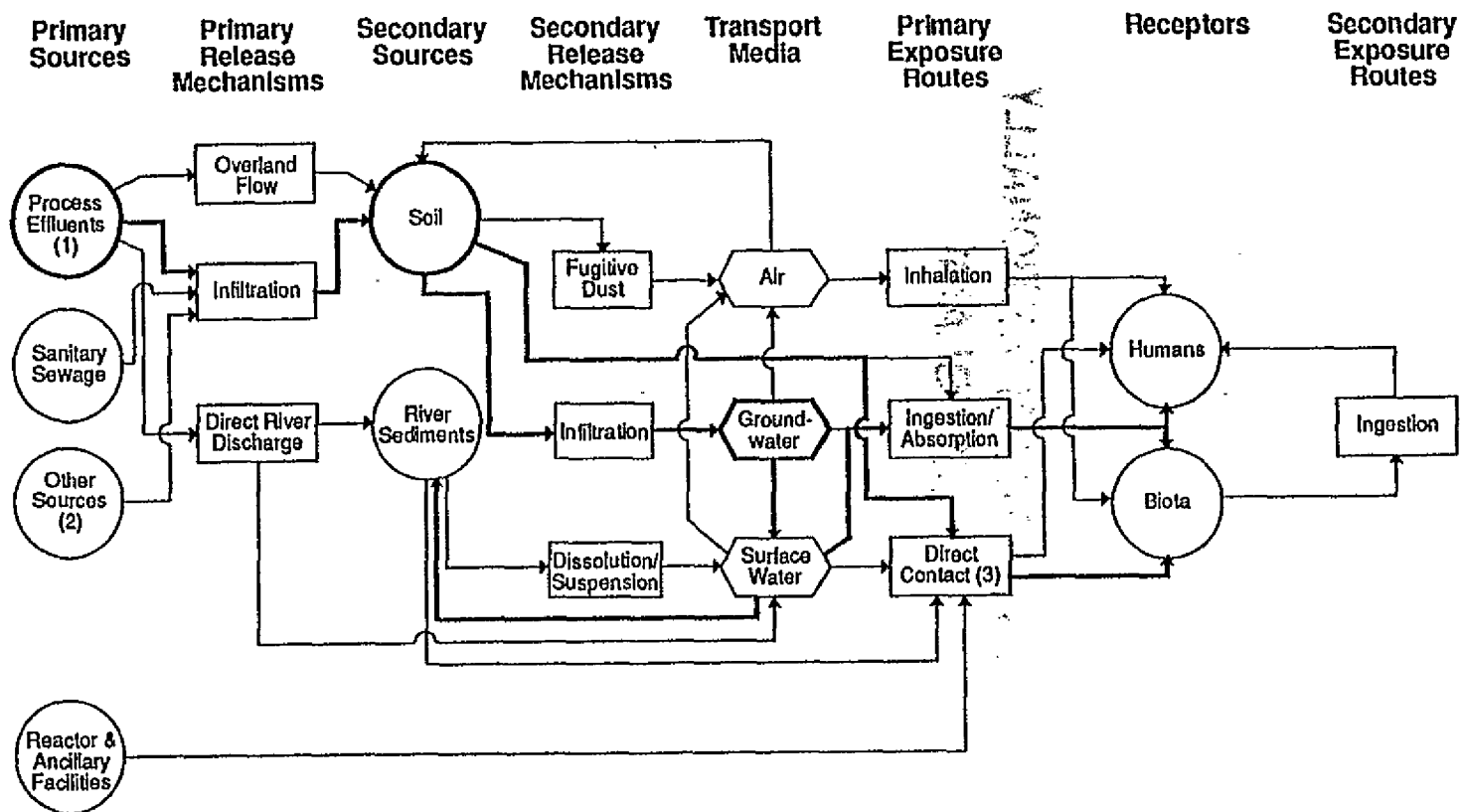
Section 2.0 presents technical information common to all four groundwater operable units addressed in this document. The information includes a description of the regional distribution of typical contamination indicators, an overview of the stratigraphic units that contain the contaminated unconfined aquifer, and a description of the interaction that occurs between groundwater from the Hanford Site and the Columbia River.

Sections 3.0 through 8.0 contain data and interpretations specific to each reactor area. These sections have been developed essentially to "stand alone," so that when information on only one operable unit is needed, it can be found in one place. Each section begins with a discussion of groundwater contaminants of concern, followed by a description of current conditions for those contaminants. The hydrogeology of the operable unit is then presented, including a description of the stratigraphy and aquifer characteristics relevant to the CSM.

Figure 1-1. Location Map for the Hanford Site



E9609083.1



- (1) Includes all facilities that received process effluents, including pipelines, basins, cribs, trenches, french drains, and outfall structures.
- (2) Includes other sources within limited existing information.
- (3) Includes exposure to radiation.

LEGEND:

- Potential Exposure Pathway
- Potential Primary Exposure Pathway
- □ Primary contaminant sources and known contaminated media

Figure 1-2. Contaminant Exposure Pathways for a Groundwater Operable Unit

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2.0 CONTAMINANT HYDROGEOLOGY OF THE 100 AREA

This section provides an overview of information common to each of the 100 Area groundwater operable units. The topics covered are regional groundwater contamination, principal sources for groundwater contaminants, and interaction between the Hanford Site aquifer and the Columbia River.

2.1 REGIONAL GROUNDWATER CONTAMINATION

A map showing the distribution of principal groundwater contaminants in the 100 Area is shown in Figure 2-1. This map depicts current conditions, as represented by averaging results for samples collected since January 1, 1995. The contaminants included on the map—chromium, nitrate, strontium-90, and tritium—represent common liquid effluents that were disposed of or leaked into the soil column during reactor operations. The reference concentration levels chosen to represent the plumes are the EPA's maximum contaminant levels (MCL).

The map in Figure 2-1 also includes water table elevation contours that describe average conditions over a recent full-seasonal cycle. Contours are used to infer the direction and rate of groundwater movement. Flow is generally oriented perpendicular to the contours and from the center of the region toward the Columbia River.

Most movement of contaminated groundwater from reactor operations has been toward the river shoreline within the reactor area. Exceptions occur at the 100-D/DR and 100-F Areas. During reactor operations, contaminated groundwater from the 100-D/DR Area moved north and northeastward, across the river horn toward the 100-H Area. The chromium plume contours near the 100-H Area illustrate the current location of this contaminated water.

The nitrate plume contour at the 100-F Area illustrates a different process. A buried former river channel runs north and south through the 100-F Area. This channel forms a preferential pathway for groundwater flow, since the channel contains more transmissive sediments than the adjacent banks. The channel has been instrumental in the widespread dispersal of contamination from 100-F Area sources, as indicated by nitrate concentration contours.

The uppermost unconfined, contaminated aquifer is contained within sedimentary deposits generally composed of loosely consolidated sands and gravels. These sediments were primarily deposited in a dynamic river environment (Lindsey, 1991). Figure 2-2 shows the nomenclature assigned to the principal stratigraphic units. The units most commonly involved in groundwater contamination descriptions are the "gravel-dominated" facies of the Hanford formation (informal nomenclature) and "Unit E" of the formally defined Ringold Formation. Depending on location, the water table is normally situated in either of these two units. The contact between the base of Ringold Unit E and the underlying Unit C typically represents the base of the uppermost unconfined aquifer.

General water chemistry for 100 Area groundwater is illustrated in Figure 2-3. The figure is a trilinear plot of dissolved ionic constituents that uses separate triangles for cations and anions. The data plotted were selected from wells located away from the core of major plumes so that the resulting characterization would not be overly influenced by contaminants. The wells are screened in the Hanford formation, Ringold Formation Unit E, and Ringold Formation Upper Mud Unit. The plots indicate that the groundwater may be generally classified as a calcium-bicarbonate water type.

2.2 PRINCIPAL REACTOR AREA SOURCES FOR CONTAMINANTS

A detailed description of the reactors, associated facilities, and production operations is contained in a Hazards Summary Report for the Production Reactors (General Electric, 1963). More recent descriptions of reactor operations from the perspective of waste sites and accidental releases are presented in technical baseline reports for each reactor area. These reports were prepared by the Environmental Restoration Program as part of RI/FS activities. (See individual reactor area sections for references.) The following summary of potential sources for common contaminants draws substantially from these sources.

2.2.1 Retention Basins and Coolant Water Pipelines

Large volumes of treated Columbia River water were used as coolant for the 100 Area's single-pass reactors, which operated between 1949 and 1971. Sodium dichromate was added to the water to provide corrosion protection for piping. While in the reactor, impurities in the water became activated by the intense neutron flux, creating short- and long-lived radionuclides. After passing through the reactor, the coolant flowed through large-diameter underground piping to retention basins. There it was held for a short period for thermal and radioactive cooling. From the retention basins, the coolant water was normally discharged into the main channel of the Columbia via outfall pipes.

Significant leakage of coolant water occurred from underground piping and retention basins. Groundwater mounds on the order of 8 m (25 ft) higher than natural water table elevations were created under these basins, and the entire subsurface underlying the reactor area was heated well above ambient temperatures (Brown, 1963). Riverbank seepage of hot coolant water created active springs along the shoreline adjacent to each reactor area. After reactor operations ceased, the coolant water mounds dissipated relatively quickly. However, significant amounts of residual coolant water undoubtedly remained in the partially saturated sediments that overlie the natural water table. Slow release of contaminants by diffusion from these partially saturated sediments can be expected to continue for many years.

Coolant water leakage to the soil column resulted in widespread chromium plumes. Based on a sodium dichromate concentration of 2 mg/L in the coolant water, a maximum concentration of hexavalent chromium (the form of chromium that results from dissociation of sodium dichromate in water) would have been approximately 700 $\mu\text{g/L}$. This concentration would have been immediately reduced as the coolant water mixed with groundwater. Other coolant water-related


releases of chromium to the soil column involved stock solutions of sodium dichromate, which contained much higher concentrations of chromium. The leakage and spillage occurred from storage tanks, pumping/mixing facilities, and underground piping.

2.2.2 Liquid Waste Disposal Trenches

Occasionally, fuel elements in the reactor would rupture, causing fragments of highly radioactive materials to be included in the coolant flow. During early reactor operations, this contaminated flow would be discharged to small soil column disposal facilities (e.g., "Pluto" cribs) located near the reactor buildings. Subsequently, the flow was diverted to much larger liquid waste disposal trenches located near the retention basins and Columbia River. The cribs and trenches were primary sources for introducing radionuclide contamination to groundwater.

Water also was used as a coolant and radiation shield for fuel rods stored in basins at each reactor building. Liquid waste disposal trenches, "percolation trenches," and tile fields were used to dispose of once-through cooling water and other effluent associated with the fuel storage basins. These waste facilities were sources for tritium and other radionuclides that contaminated the soil column and underlying groundwater.

2.2.3 Miscellaneous Soil Column Disposal Facilities



Various acid solutions, which commonly included nitric, sulfuric, and chromic acids, were used to decontaminate equipment associated with reactor operations. While involving much smaller volumes than coolant water discharges, these solutions collected considerably higher concentrations of contaminants, including radionuclides and metals. They were typically discharged to small soil column disposal facilities, such as cribs, French drains, and trenches, located near the reactor buildings. Occasionally, decontamination solutions were disposed of in the coolant water effluent stream that went to the retention basins or to the adjacent liquid waste disposal trenches.

2.3 GROUNDWATER-RIVER INTERACTION

The Columbia River is a "gaining stream" as it passes through the Hanford Reach. The river receives a net gain of water as the result of inflow from the unconfined aquifer into which the river has cut its channel. There is also a very minor addition of water from surface runoff. The movement of groundwater from the aquifer into the river channel is driven by the hydraulic gradient between the water table at some distance inland from the river (higher elevation) and the river surface (lower elevation). The rate of groundwater flow is determined partly by the steepness of this gradient.

The hydraulic gradient varies with several cycles. A seasonal cycle, which affects the entire system, is caused by annual precipitation and temperature differences in the river's drainage basin. Seasonal cycles for the last several years are illustrated by daily average outflows for Priest Rapids Dam (Figure 2-3), which is located immediately upstream of the Hanford Site.

Weekly and daily cycles are caused by river stage fluctuations associated with the numerous dams on the river. The shorter-term cycles are determined by electrical power generation needs, water management for fisheries resources, and other operational needs for the dams.

Fluctuations in river stage cause hydraulic gradients in the aquifer immediately adjacent to the shoreline to be highly variable. Within the first several hundred feet inland, gradients regularly reverse direction during high river stage, and river water moves into the banks of the channel. As the river cycles in elevation, so do water levels in wells along the shoreline. A wave, or pressure pulse, propagates inland from the river and can be easily measured up to a distance of at least 2,000 ft (600 m). The characteristics of this wave can be used to infer hydraulic properties associated with the aquifer (e.g., McMahon and Peterson, 1992).

Groundwater contaminant plumes meet uncontaminated river water in two general zones of interaction: (1) a riverbank storage zone in which river water moves alternately in and out of the bank as the river stage fluctuates, and (2) a continuously submerged zone at the bottom of the river channel. The processes that occur in these two zones have significant implications regarding the prediction of contaminant concentrations at points of exposure for humans and aquatic organisms in the river environment. Figure 2-4 is a generalized cross section drawn through a typical reactor area and the adjacent Columbia River channel. The cross section is used to illustrate the two zones that are discussed below.

2.3.1 Bank Storage of River Water

This river water, along with groundwater that has backed up because of the high river stage, is referred to as "bank storage" (Newcomb and Brown, 1961). River water that moves into the bank storage zone may (1) overlie groundwater, (2) layer with groundwater, and/or (3) mix with groundwater. There is very limited field evidence to evaluate the relative dominance of these three processes, and all three are likely to occur to some degree within a segment of shoreline.

When river stage falls, which may occur fairly rapidly, bank storage drains back into the channel and frequently appears as riverbank seepage. Analysis of riverbank seepage water typically reveals contaminant concentrations that are intermediate between groundwater from nearby wells and near-shore river water (Peterson and Johnson, 1992). Figure 2-5 illustrates the general relationship between concentrations observed in near-river wells, riverbank seepage, and near-shore river water, using specific conductance (a measure of dissolved salts) as an indicator.

The composition of riverbank seepage observed at any particular time is a function of the amplitude and duration of previous river stage fluctuations. The composition may vary with seasonal cycles and in response to daily river cycles. Unusually low or high river conditions, as experienced during the winter of 1995/1996 and the following spring, have a profound influence on water quality analyses of riverbank seepage.

2.3.2 Groundwater/River Water Interface within the Riverbed Substrate

Groundwater also meets river water in a zone located beneath the zone of bank storage and within the river channel. The interface occurs either within the sediments at the bottom of the river channel or, if no sediments are present, above the riverbed in the river flow. Where sediments are present, the depth at which the mixing of groundwater and river water occurs determines the contaminant concentrations to which aquatic receptors in the substrate may be exposed. Most areas of the Hanford Reach channel are covered by sediments.

Some areas of Hanford Reach river substrate are composed of gravelly sediments that provide spawning habitat for fall chinook salmon. Salmon may excavate egg pockets to depths of approximately 40 cm (16 in.) (Chapman, 1988). If inflowing groundwater meets river water at this or shallower depths in the sediment, the eggs and subsequent alevin could be exposed to contaminants carried by the groundwater.

Sampling of sediment pore water in the Hanford Reach has been conducted to determine the concentration of chromium at depths of 46 cm (18 in.) in gravelly sediments adjacent to known chromium plumes in groundwater (Hope and Peterson, 1996a and 1996b). Several areas have been found to contain chromium at concentrations that exceed the EPA's ambient water quality criteria (AWQC) for protection of freshwater aquatic organisms. The results of these sampling projects are summarized in the sections for individual operable units.

2.3.3 Interpreting Water Quality Data Collected at Locations Near the River

Water samples are collected from a variety of locations near the river, to provide observational evidence for the characteristics of contamination moving into the river via groundwater flow. Monitoring wells and riverbank seepage sampling have been used historically for this purpose. Recently, new data have been obtained by collecting pore water from sample ports installed by divers in the river substrate, and by sampling temporary tubes driven into the aquifer along the shoreline (Hope and Peterson, 1996b). These data provide key evidence for interpreting monitoring results from shoreline locations and for predicting concentrations at locations where direct sampling is impractical.

Contamination was introduced to groundwater via infiltration through the overlying soil column, so most contamination is expected to remain in the upper part of the unconfined aquifer. Also, groundwater flow toward the river is faster in the loose, gravelly sediments in the upper levels of the unconfined aquifer than in deeper, finer-grained sediments. Therefore, contamination moves faster laterally than it does vertically (downward), and contamination may be layered. Existing monitoring wells may have screened or perforated casing intervals that span more than the contaminated layer. Consequently, concentrations measured in some samples may be biased toward lower values by the inclusion of uncontaminated water.

The "age" of a groundwater plume is a factor when correlating concentrations observed in monitoring wells with concentrations measured in riverbank seepage, shoreline sampling tubes, and near-shore river water. Since the waste disposal practices that created groundwater plumes

generally stopped by the late 1960s, most plumes have migrated and been dispersed by natural processes—they may be described as “mature.” Samples from nearshore monitoring wells may represent the “backside” of more concentrated plumes that have already passed the well and discharged into the river.

Groundwater Contamination in the 100 Areas

Figure 2-1. Regional Distribution of Groundwater Contamination in the 100 Area

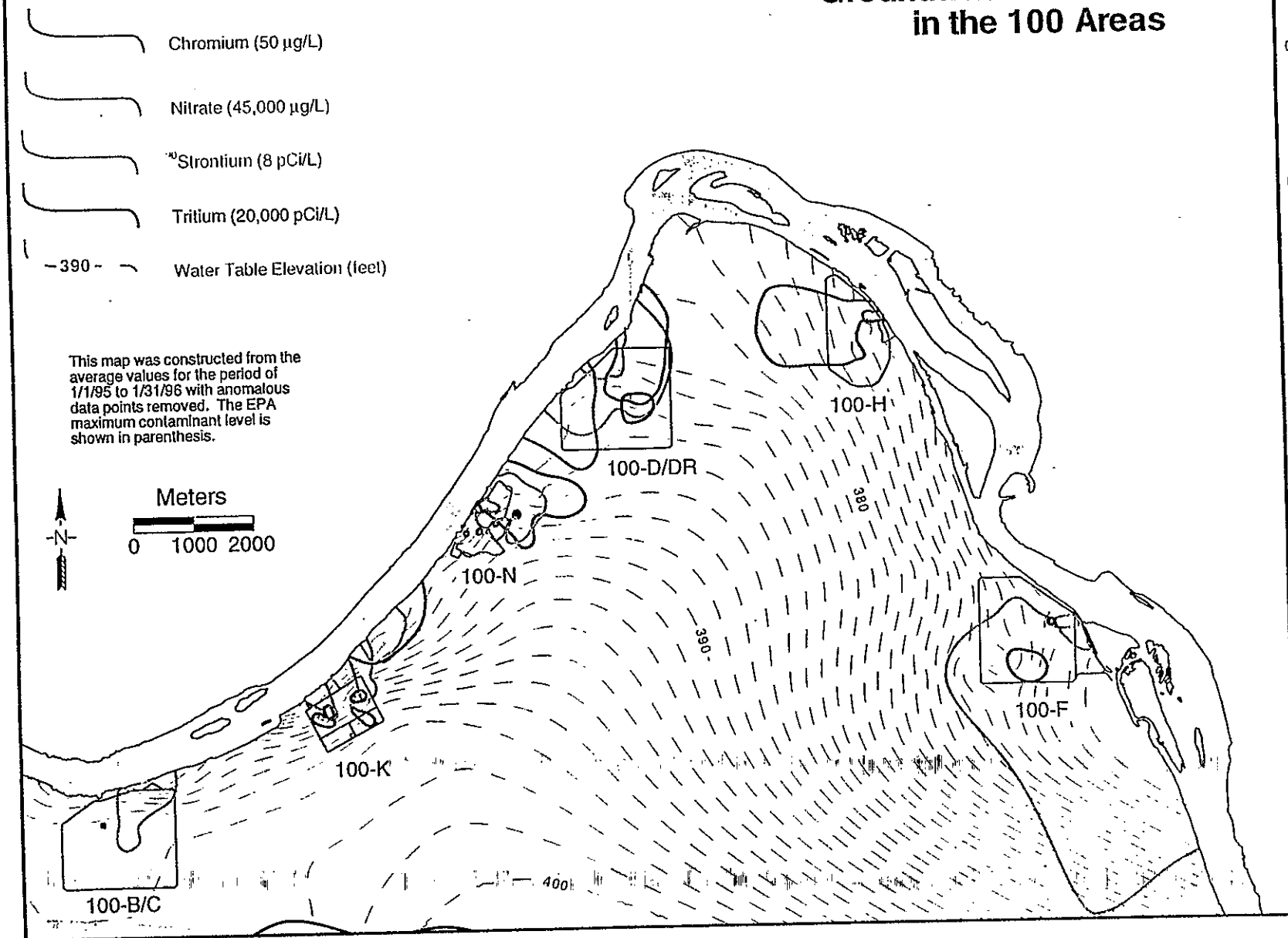
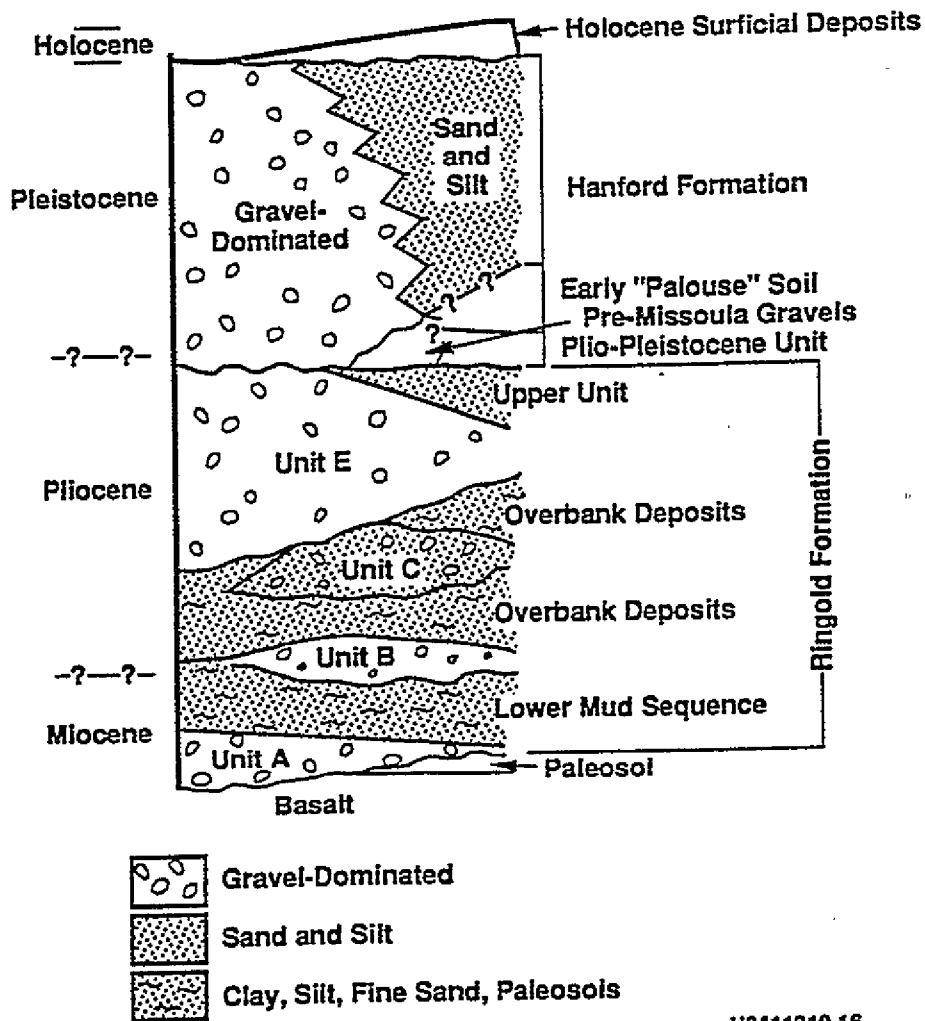
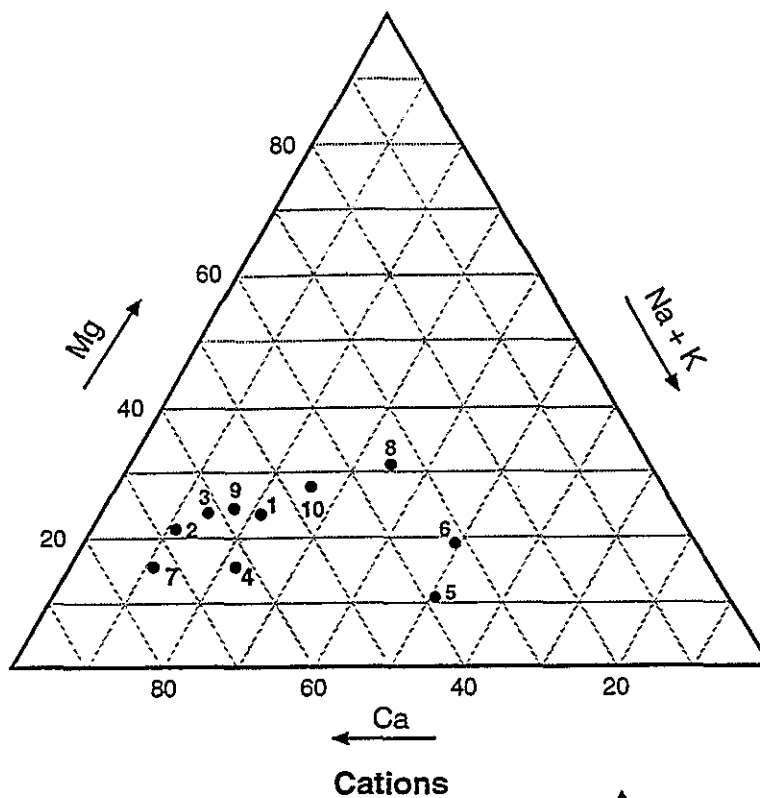


Figure 2-2. Generalized Stratigraphy for the 100 Area (Delaney et al., 1991)



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Figure 2-3. General Characterization of Groundwater Chemistry



1. H3-1, Hanford fm/Ringold Upper Mud
2. D8-55, Hanford formation
3. 699-96-49, Ringold Fm, undifferentiated
4. K-11, Ringold Fm, Unit E
5. F5-43A, Hanford fm
6. F5-43B, Ringold Formation, Upper Mud
7. K-32A, Ringold Formation, Unit E
8. K-32B, Ringold Formation Unit C, Paleosol-Overbank
9. B8-6, Hanford Formation/Ringold Unit E
10. B2-12, Ringold Formation Unit E

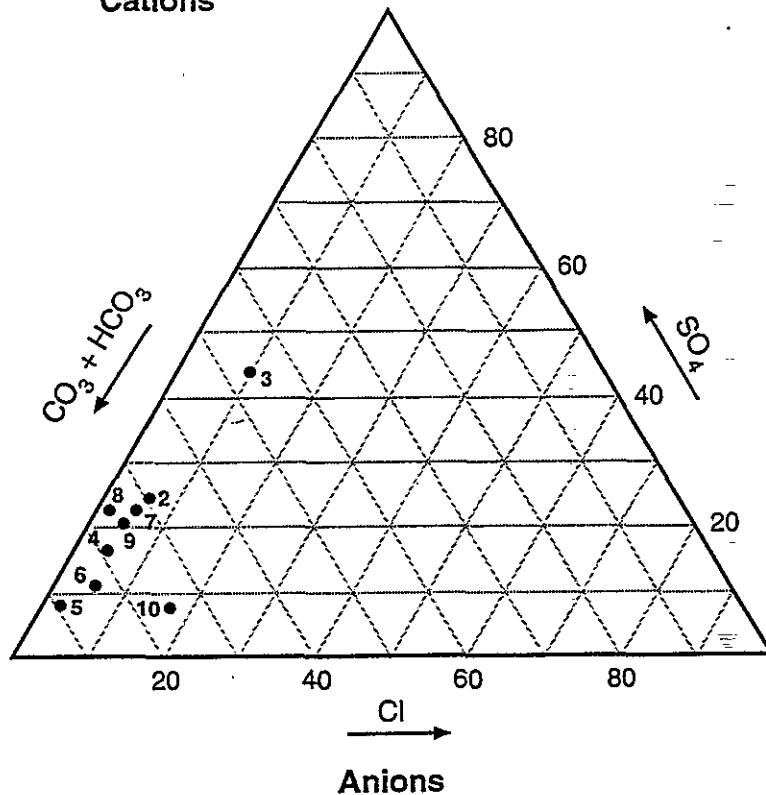
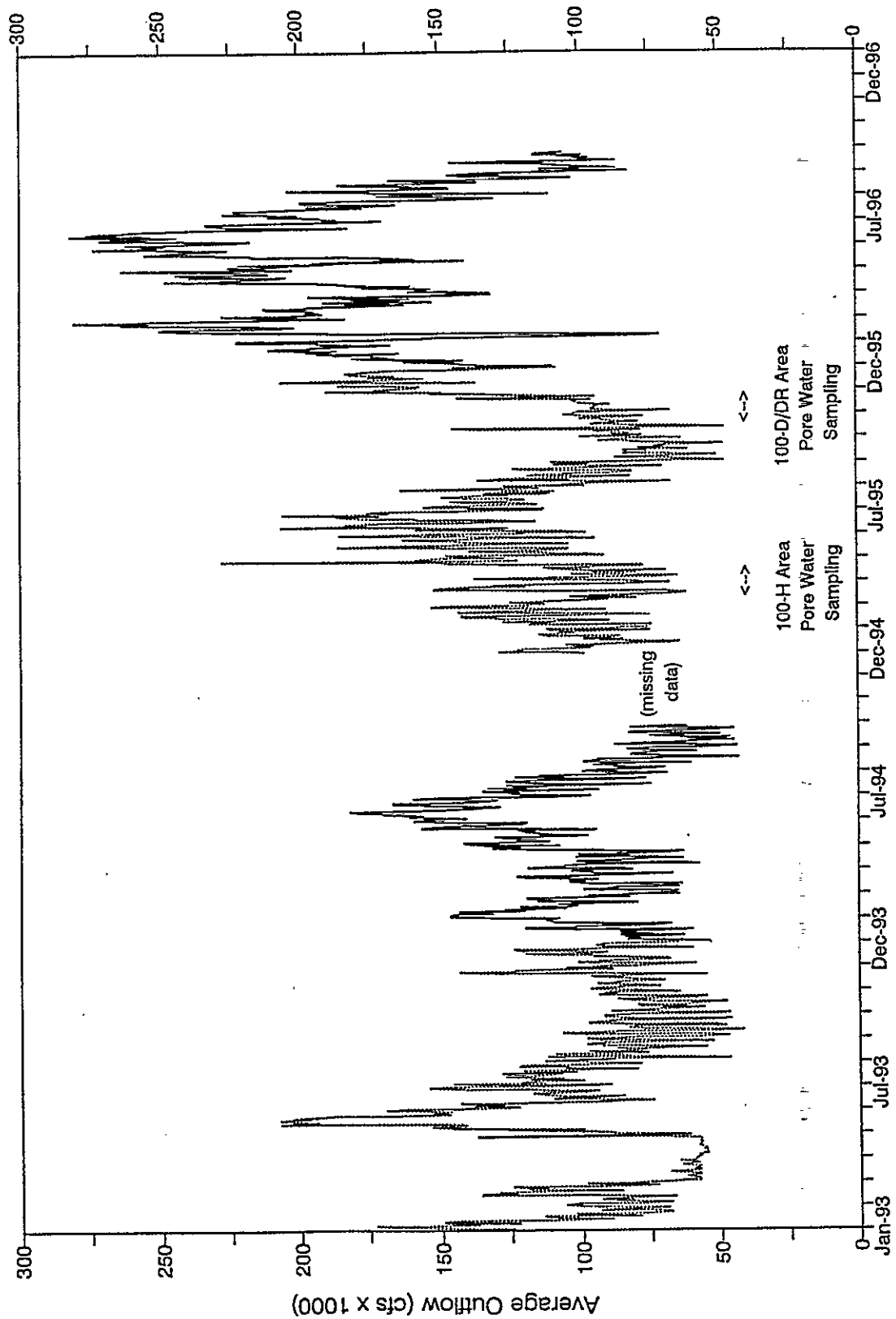


Figure 2-4. Average Daily Outflow of Priest Rapids Dam, 1993 to 1996



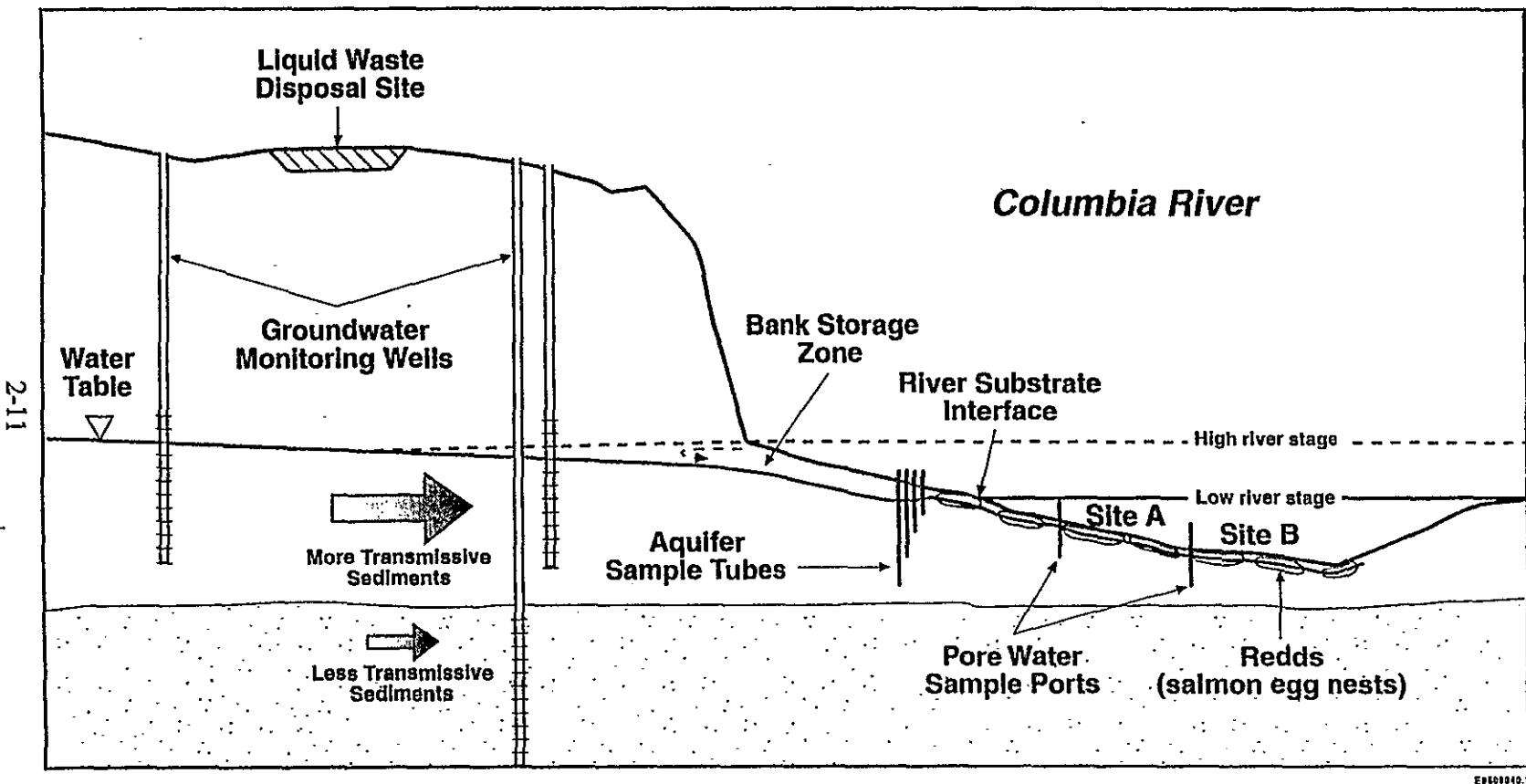
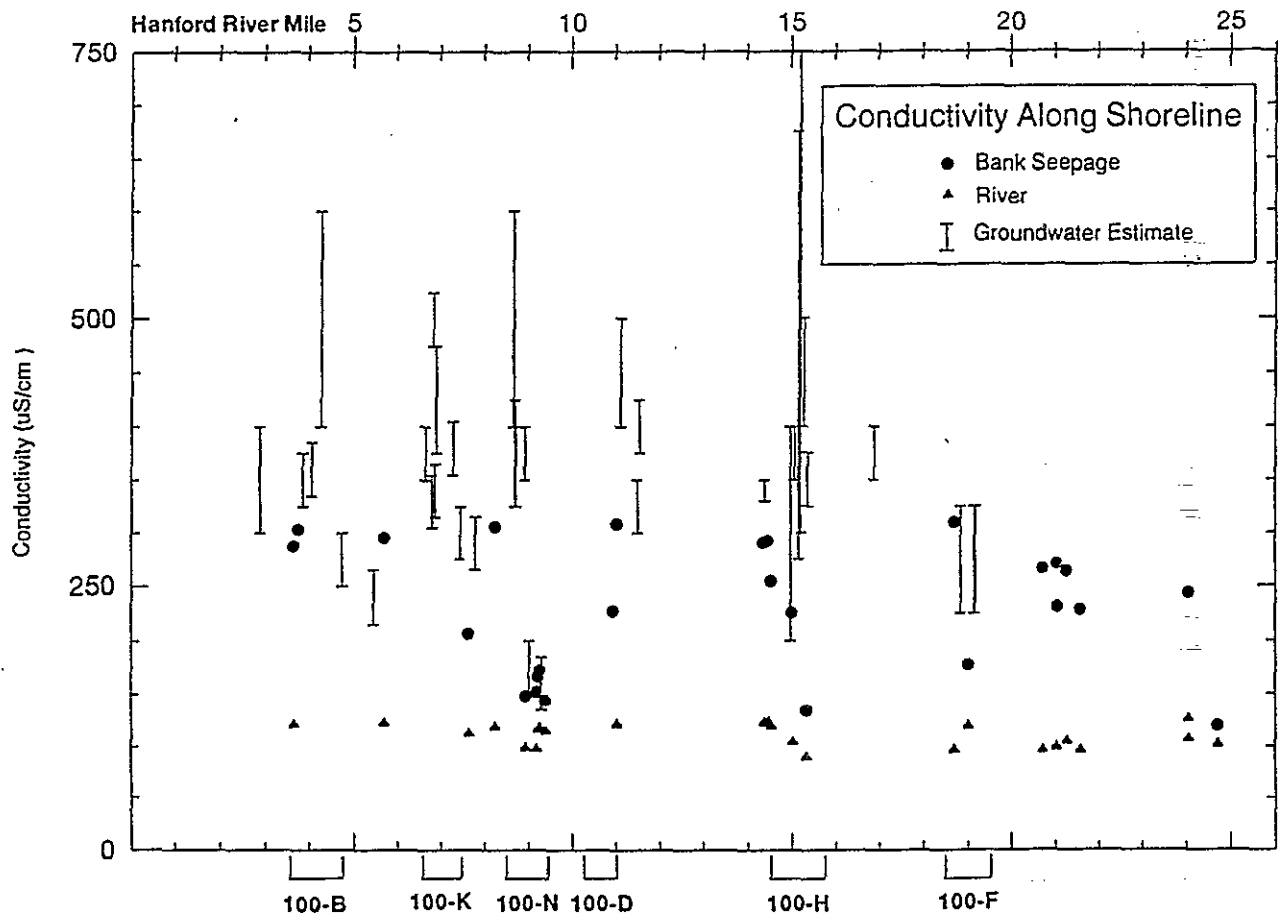


Figure 2-5. Conceptual Model for Groundwater-River Interaction
(Hope and Peterson, 1996b)

Figure 2-6. Specific Conductance in Near-River Wells,
Riverbank Seepage, and Near-Shore River Water (Johnson and Peterson, 1992)



3.0 100-BC-5 OPERABLE UNIT

The 100-BC-5 Operable Unit Contains the groundwater underlying the 100-B/C Area. It also includes adjacent areas where contaminated groundwater from the 100-B/C Area may pose a risk to human and ecological receptors. Examples of adjacent areas are the riverbed, where groundwater may upwell into sediments that form habitat for aquatic life, and locations where water seeps from the riverbank during low river conditions. Figure 3-1 is an index map for the 100-B/C Area that shows the locations of groundwater monitoring wells and facilities/waste sites discussed in the text.

The following sections describe contaminants of concern, their distribution, how they change with time, and the hydrogeologic framework through which they move.

3.1 CONTAMINANTS OF CONCERN

Contaminants of concern may be chemical and radiological constituents that pose a risk to human and/or ecological receptors. Numerous regulatory requirements, such as the U.S. Environmental Protection Agency's (EPA) drinking water standards (40 CFR 141 "maximum contaminant levels" [MCL]) and ambient water quality criteria (AWQC) for protection of freshwater aquatic organisms, help identify which constituents are of concern.

A limited field investigation (LFI) was completed for the 100-BC-5 Operable Unit (DOE-RL, 1994a) that identified contaminants of potential concern based on a limited set of data collected in 1992 and 1993. These constituents were used in a qualitative risk assessment, the results of which were used to make decisions regarding an interim remedial measure (IRM). The contaminants of concern, conclusions, and recommendations contained in the LFI report are as follows:

Operable Unit	Human Health Risk	Ecological Risk	LFI Conclusion and Recommendation
100-BC-5	Carbon-14 Strontium-90 Technetium-99 Tritium	Aluminum Chromium Iron Nickel	An IRM is not required because of the low risk associated with current site usage. Remove from IRM pathway. Continue monitoring until source remediations are complete, then reevaluate risk.

Source: Limited Field Investigation Report (DOE-RL, 1994a)

These contaminants of concern have been tracked primarily by semiannual sampling of wells during the later stages of the LFI phase of the remedial investigation/feasibility study (RI/FS). As sufficient information becomes available to demonstrate that a constituent is no longer of concern with respect to human health and ecological risk, it is typically removed from the

monitoring schedule. However, data for some discontinued contaminants of concern may continue to accumulate because the constituent is part of a grouped analysis (e.g., analysis of metals by inductively coupled plasma [ICP]).

3.1.1 Summary of Current Groundwater Contamination Levels

Recently observed concentrations for contaminants of potential concern identified during the LFI, and for additional waste and water quality indicators, are presented in Table 3-1. This table includes all results contained in the Hanford Environmental Information System (HEIS) database for sampling more recent than January 1, 1995 (generally inclusive of sampling conducted through January 1996). Semiannual sampling has been the norm since the last half of 1994, so this summary is generally based on two or three sampling events per well.

Initial data evaluation processing has been completed on the entire data set summarized in Table 3-1 (i.e., assigning common units, removing duplicate entries, and correcting known errors in reported results). The full data evaluation process has been completed for chromium, nitrate, strontium-90, tritium, and specific conductance (see Ford and Denslow, 1996 for a description of the data evaluation process for data extracted from HEIS). Some values in Table 3-1 for constituents other than the five listed above may be less representative of aquifer conditions than values for fully evaluated constituents.

The list of constituents that currently exceed regulatory standards is similar to the list of contaminants of potential concern identified during the LFI. Aluminum, chromium, and iron are elevated in several wells and are of concern for ecological risk. Nickel no longer exceeds standards in 100-B/C Area wells. Strontium-90 (and gross beta activity) and tritium remain slightly elevated in several wells. Carbon-14 and technetium-99 concentrations are well below standards. Table 3-2 identifies the 100-B/C Area wells in which various constituents that are included in Table 3-1 exceed standards.

3.1.2 Sources for Contamination in Groundwater

The principal surface facilities associated with liquid waste disposal to the soil column are shown in Figure 3-1. A detailed description of these waste-generating facilities is contained in the "100-B/C Area Technical Baseline Report" (Carpenter et al., 1994). A description of how the plutonium production reactors operated is presented in the "Hazards Summary Report" for the production reactor plants (General Electric, 1963). Both documents provide comprehensive background material for interpreting the origin of groundwater contamination. The source information contained in the following summary is derived from those documents, unless otherwise cited.

The greatest volumes of liquid waste were associated with the retention basins and effluent pipelines that lead to the basins from the 105-B reactor building. These facilities handled reactor coolant effluent that contained radionuclides and hexavalent chromium. Significant leakage of this effluent occurred from the pipelines and the retention basins. Although shorter-lived radionuclides in the leakage decayed away quickly, longer-lived radionuclides were retained on

the sediments in the soil column. Hexavalent chromium moved unimpeded downward through the soil column and into the underlying groundwater.

It has been estimated that approximately 1.5 million cubic feet (11.2 million gal per day) of coolant entered the soil column from these facilities (Brown, 1963). Sodium dichromate was added to coolant makeup water to form a solution of 2 mg/L sodium dichromate. The sodium dichromate dissociated to create a maximum 700 $\mu\text{g/L}$ concentration of hexavalent chromium. At this concentration, the leakage of used coolant would have introduced slightly less than 30 kg per day of hexavalent chromium to the soil column, which was subsequently dispersed by groundwater flow.

The leakage of coolant effluent from the pipelines and retention basins was sufficient to create mounds on the natural water table, thus altering the normal pattern for groundwater flow through the 100-B/C Area. Some groundwater containing contamination may actually have been driven inland by the mounding, to later return under the influence of the natural water table gradient. Mounding is likely to have caused a more widespread distribution of chromium in groundwater than any other chromium source.

Liquid waste disposal trenches, which are located near the Columbia River, received highly contaminated coolant water that resulted when a fuel element ruptured. Reactor coolant effluent was diverted to these facilities for soil column disposal to allow more time for shorter-lived radionuclides to decay prior to entering the river, and to allow the soil column to absorb and retain the longer-lived radionuclides. Residual groundwater contamination associated with these trenches includes chromium and radionuclides, especially strontium-90.

Other prominent liquid waste disposal sites include small cribs and french drains near the reactor buildings. These facilities were typically used to dispose of decontamination solutions, including nitric and chromic acids, that contained metals and radionuclides. Each reactor also had a "fuel storage basin percolation pit," which was used to dispose of once-through coolant water for the fuel storage basins. These facilities were a source of tritium and other radionuclides.

As part of source operable unit investigations, summaries of waste sites have been prepared that list known waste sites, describe their characteristics, and indicate the contaminants of concern associated with each site. These summaries were originally presented in the proposed plans for the 100-BC-1 and 100-BC-2 Operable Units (DOE-RL, 1995c and DOE-RL, 1995d), and are included here as Tables 3-3 and 3-4.

3.2 CONTAMINANT DISTRIBUTION MAPS AND TREND CHARTS

To illustrate the current distribution of contamination in 100-B/C Area groundwater, data for samples obtained since January 1, 1995, for chromium and strontium-90 concentrations have been plotted on maps. The concentrations plotted are average values of data from HEIS that have undergone the full data evaluation process (Ford and Denslow, 1996). This process is intended to produce concentration values that accurately represent aquifer conditions. The

average values presented do not include results considered nonrepresentative ("outliers") by the data evaluator. Chromium results are for filtered samples, since these data provide the best indicator of chromium that is dispersed by groundwater flow.

The maps include water table contours for long-term average elevations (January 1, 1994, through August 30, 1995). Groundwater flow is generally oriented perpendicular to the contour lines.

Chromium is near or slightly elevated above the MCL of 50 $\mu\text{g/L}$ in two areas (Figure 3-2). The first is near the river on the downgradient side of the retention basins, where an average value of 44 $\mu\text{g/L}$ is present in well 199-B3-47. Concentrations have been increasing in this well since it was installed in 1992 (Figure 3-3). Adjacent well 199-B3-1 reveals lower chromium concentrations that are near typical detection limits. A second nearby well (199-B2-12), which monitors a horizon well below the water table, shows evidence of chromium, with concentrations averaging 20 $\mu\text{g/L}$ (Figure 3-3). Chromium at this location may represent residual contamination from the reactor coolant effluent pipelines and retention basins.

The second area of elevated chromium (Figure 3-2) is downgradient of former water treatment facilities where coolant water was prepared, a process that included the addition of sodium dichromate. Sodium dichromate may have leaked from storage tanks and transfer facilities. The single monitoring well in this area (199-B5-1) has an average concentration of 60 $\mu\text{g/L}$ (Figure 3-3), with widely fluctuating results, the cause for which is unknown.

The average concentrations plotted on Figure 3-2 are for analyses of total chromium in a filtered sample. Of the two common valence states for chromium, the hexavalent form is soluble and the trivalent form insoluble (i.e., associated with particulate matter). Therefore, the results in Figure 3-2 are generally representative of hexavalent chromium, which is the form most toxic to aquatic organisms.

Strontium-90 is slightly elevated in an area extending from the 105-B reactor building downgradient to the river (Figure 3-4). The highest average values (44 pCi/L in 199-B3-1 and 48 pCi/L in 199-B3-46) appear to be residual contamination associated with the liquid waste disposal trenches. The concentrations in 199-B3-1 are essentially constant, while the concentration in 199-B3-46 has decreased from a high of approximately 120 pCi/L in 1992, when the well was installed (Figure 3-5). Well 199-B5-2, located a short distance upgradient of the retention basins, shows a recent increase to 33 pCi/L from its earlier trend, which averaged 15 pCi/L (Figure 3-5). It is possible that the strontium-90 in this well represents residual contamination from the nearby liquid waste crib and 105-B reactor building sources.

3.3 HYDROGEOLOGY

This section describes the framework through which contamination may be transported by groundwater movement. The lithologies of the stratigraphic units, the saturated and unsaturated zones, and physical properties of the various hydro-stratigraphic units are described in the following sections.

3.3.1 Hanford and Ringold Stratigraphic Units

The most important stratigraphic units in the 100-BC-5 groundwater operable unit are the Hanford formation (informal nomenclature) and the upper Ringold Formation. Figure 3-6 is a geologic cross section perpendicular to the flow of the Columbia River. Figure 3-7 is approximately parallel to the Columbia River. These cross sections show the Hanford-Ringold contact, graphically display sediments recovered during drilling of groundwater monitoring wells, and show the range of depth to groundwater during the period from January 1, 1994, to August 30, 1995. Figure 3-1 shows the location of the geologic cross sections. Lindberg (1993a) provides a detailed description of the entire geologic section down to the top of the Columbia River Basalt.

3.3.1.1 Hanford formation. The Hanford formation in the 100-BC-5 Operable Unit is gravel dominated with sandy and silty intervals (see Figures 3-6 and 3-7). Lindberg (1993a) indicates that the Hanford formation ranges in thickness from over 30.5 m (100 ft) in the southern part of the area to 13.7 m (45 ft) near the Columbia River. The contact between the Hanford formation and underlying Ringold Formation is unconformable and varies in elevation between wells.

3.3.1.2 Ringold Formation. The upper Ringold Formation in the 100-BC-5 area is dominated by silty sandy gravel with subordinate sand- and silt-dominated interbeds. Unit E of the Ringold Formation can be identified clearly in the northeast part of the area but not clearly in the central and western part of 100-BC-5 (Lindberg, 1993a). It is clear, however, that the Hanford formation in the 100-BC-5 area is not in contact with the Ringold upper mud unit, the bottom of the unconfined aquifer.

3.3.2 Vadose Zone and Uppermost Aquifer

The vadose zone ranges in thickness from 6.6 m (21.7 ft) in well 199-B2-13, in the western part of 100-BC-5 near the Columbia River, to over 30.5 m (100 ft) in well 6-63-89 (Figure 3-6). Figures 3-6 and 3-7 reveal that the top of the saturated zone (water table) is located in the lowermost Hanford formation and uppermost Ringold Formation. Therefore, the uppermost aquifer is found mostly within the Ringold Formation and locally includes the lowermost Hanford formation. This aquifer is approximately 33.5 m (110 ft) thick in well 199-B3-2 (Lindberg, 1993a).

Geologic sections A-A' and B-B' (Figures 3-6 and 3-7) show maximum and minimum groundwater elevations measured in wells along the sections from January 1, 1994, to August 30, 1995. Wells near the river (199-B3-47) display over 1.8 m (6 ft) of range in groundwater

elevation, while wells inland (199-B9-2) display about 0.4 m (1.3 ft) of range in groundwater elevation (Table 3-5). The range in groundwater elevation in wells near the river is largely due to the effect of river stage.

The contaminant plume maps presented earlier (Figures 3-2 and 3-3) show the elevation of the water table using average depths to water measured in wells from January 1, 1994, to August 30, 1995. The approximate flow direction is north-northeast toward the Columbia River at a gradient of approximately 0.0019.

The presence of an upward hydraulic gradient is suggested in the 100-BC-5 Operable Unit by hydrographs based on data for wells completed at the water table and at a greater depth in the aquifer along the shoreline (Figure 3-8). Well 199-B3-47 is screened at an elevation of 114.7 to 121.2 m (376.2 to 397.7 ft) in the unconfined Hanford and upper unconfined Ringold Formation. Well 199-B2-12, which is located nearby, is screened between elevations 79.6 to 82.6 m (261 to 271 ft) in the first producing horizon below a confining layer in the upper Ringold Formation. The deeper well responds to river stage changes more directly and with greater change than does the shallower well.

The average groundwater elevations indicated by periodic steel tape measurement also suggest a generally upward gradient in the area monitored by these two wells (Table 3-5). The long-term average groundwater elevation in 199-B2-12 (the deeper well) is about 0.46 m (1.5 ft) higher than the average elevation in 199-B3-47 (the shallower well), suggesting a vertical (upward) hydraulic gradient. The range in groundwater elevations in 199-B2-12, 1.78 m (5.84 ft), is very similar to the range in 199-B3-47, 1.95 m (6.39 ft), suggesting that 199-B2-12 is being influenced by loading by the river and the direct transfer of pressure. Infrequently and during very low river conditions, groundwater elevations in 199-B2-12 are slightly below those of 199-B3-47.

3.3.3 River Influence on Monitoring Wells

Water level elevations and specific conductance are used to qualitatively evaluate the influence the river has on monitoring wells. Table 3-6 summarizes water level elevations and specific conductance for each 100-B/C Area well, and shows the well's distance inland from the river low-water shoreline. The wells are separated into two groups in the table: (1) those that have screened or perforated open intervals that include the water table and (2) those that are open at depths in the aquifer well below the water table.

Data for Table 3-6 were extracted from HEIS in the form of depth-to-water measurements. These values were combined with recent top-of-casing surveys, using either results from an extensive 1993 U.S. Army Corps of Engineers survey, or, when Corps data are not available, results from a recent ICF Kaiser Hanford, Inc., survey. These surveys are referenced to baseline monuments, the locations of which were re-established by the Corps in 1993. All data are referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

The average water level elevation is for data obtained during the period from January 1, 1994, through August 30, 1995. This average represents long-term conditions over slightly more than a seasonal cycle. The range between minimum and maximum water level elevations provides a measure of the degree to which river stage fluctuations influence the well. The range is also influenced by the degree to which the aquifer segment intercepted by the well is confined. In response to river fluctuations, more confined segments produce greater changes in well water levels.

Values for specific conductance are also included in Table 3-5. Specific conductance, which varies with the amount of dissolved salts in the groundwater, can be used to identify water of various origins. River water is typically in the range of 120 to 140 $\mu\text{S}/\text{cm}$. Groundwater from the Hanford gravels is approximately 400 $\mu\text{S}/\text{cm}$, while water from the Ringold Formation appears to be approximately 300 $\mu\text{S}/\text{cm}$, although data to support the latter are limited. Given these contrasts, specific conductance is useful in helping to describe the interaction between river water and groundwater. However, where contamination is present, specific conductance may vary over a wide range, thus reducing its usefulness as a mixing indicator for natural waters.

3.3.4 Aquifer Properties

Slug tests were performed in monitoring wells completed during the 1992 100-BC-5 Limited Field Investigation (DOE-RL, 1994a). Hydraulic conductivities were calculated in wells 199-B2-12, 199-B2-13, and 199-B3-46 using the Bouwer and Rice method (Table 3-7). Other well data were not utilized because development times were too short for the effects of delayed yield to dissipate or hydraulic conductivities were too high to calculate using the Bouwer and Rice method. Following are hydraulic conductivities for the three wells listed above:

- 199-B2-12, in the semiconfined Ringold, $K = 0.0007 \text{ cm/s}$ to 0.002 cm/s
- 199-B2-13, in the unconfined Hanford, $K = 0.02 \text{ cm/s}$
- 199-B3-46, in the unconfined Ringold/Hanford, $K = 0.005 \text{ cm/s}$.

3.3.5 Physical Properties of Aquifer Materials

Table 3-8 is a summary of physical properties for 11 samples collected from wells 199-B2-12, 199-B4-9, and 199-B9-2. Particle size, specific gravity, bulk density, moisture content, and saturated hydraulic conductivity were determined for each sample. In each well, samples were collected from the top half, bottom half, and below the water table. The sampling was biased toward finer sediments because they were easier to collect than large gravels or cobbles. The sample description is based on the particle size distribution of the sample. Water level data are included to clarify whether the sample was collected from the saturated zone in the well.

Figure 3-1. Well Locations and Principal Facilities in the 100-BC-5 Operable Unit

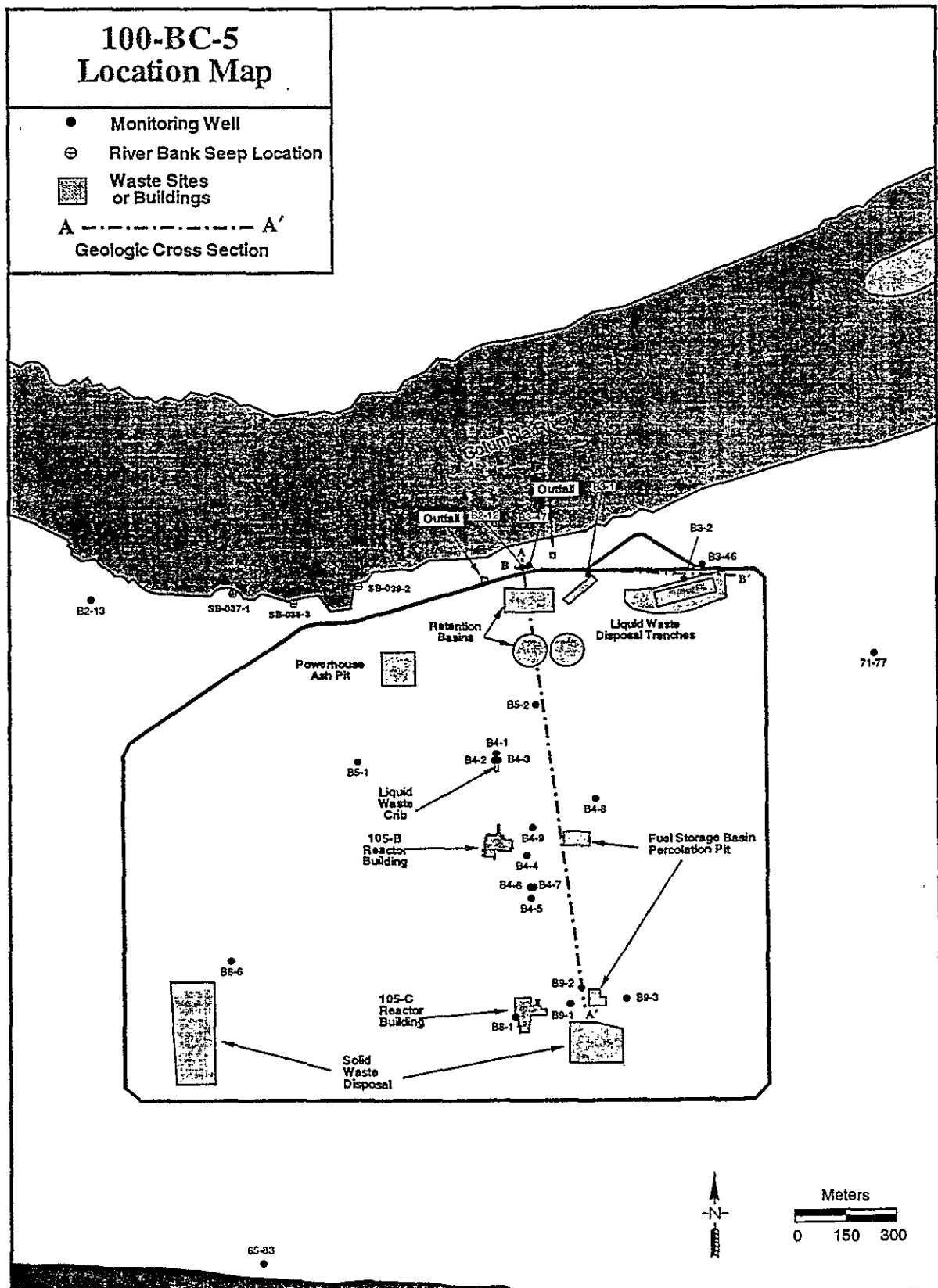


Figure 3-2. Chromium Distribution in the 100-B/C Area

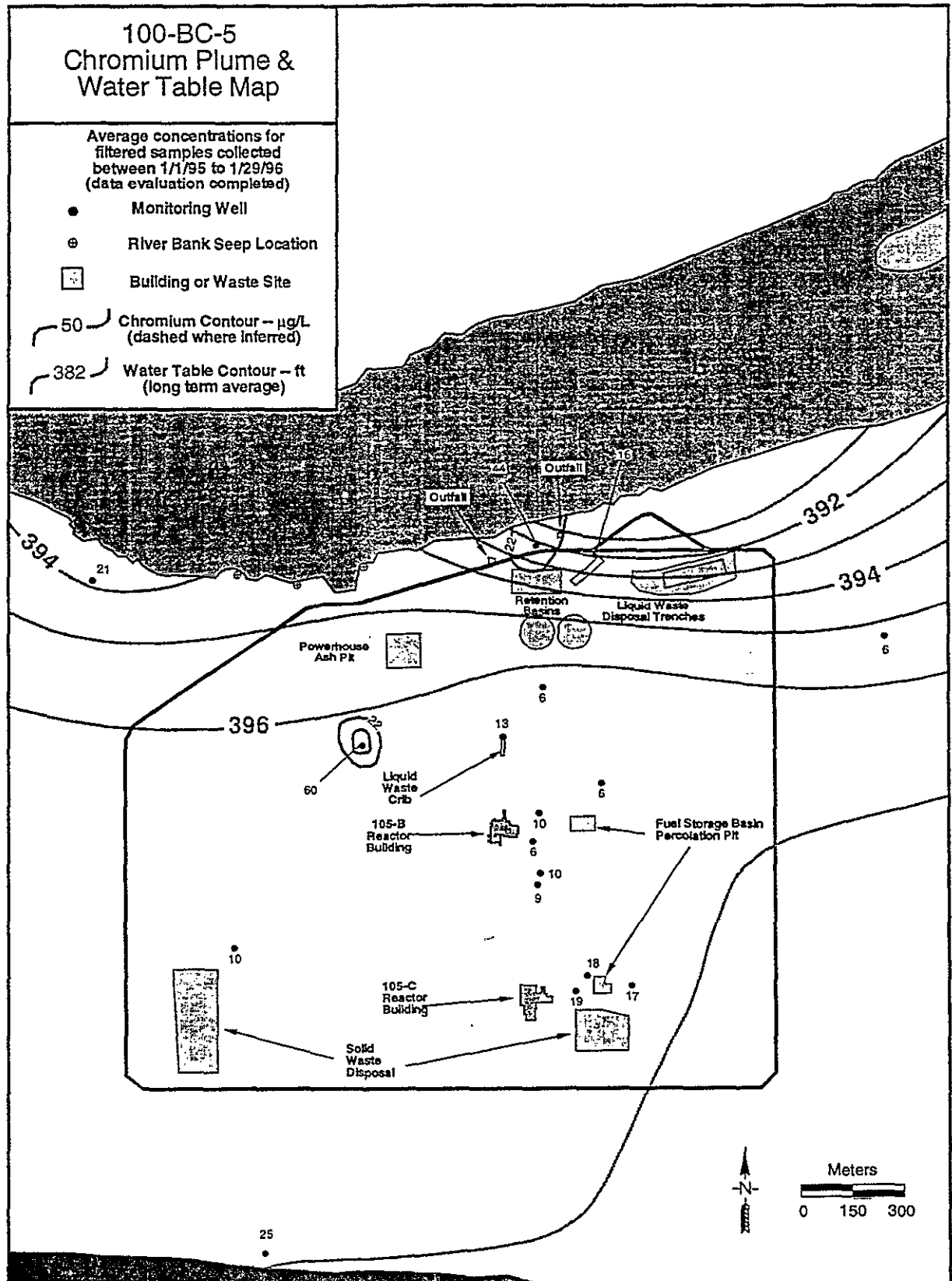


Figure 3-3. Chromium Trends in Selected 100-B/C Area Near-River Wells

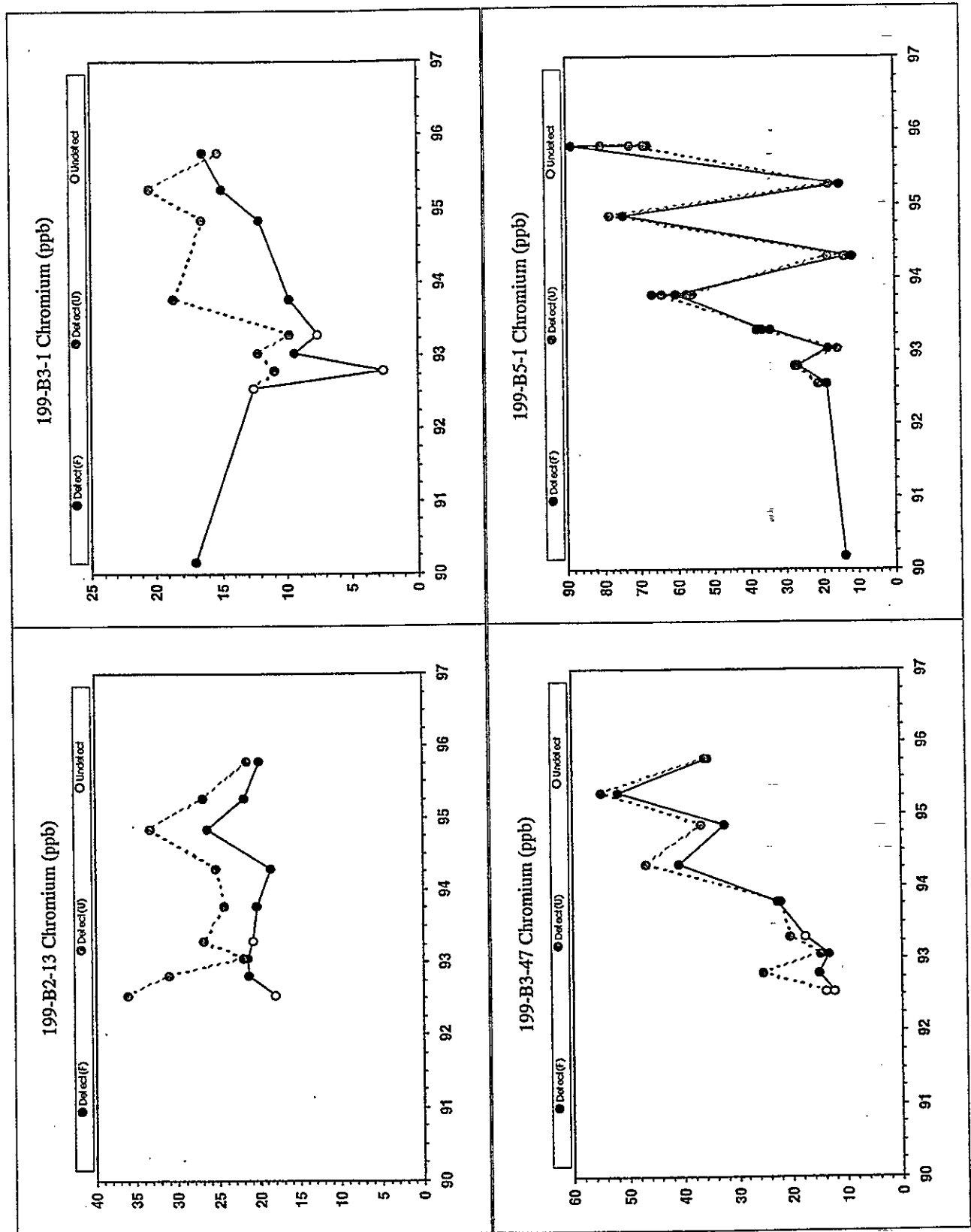


Figure 3-4. Strontium-90 Distribution in the 100-B/C Area

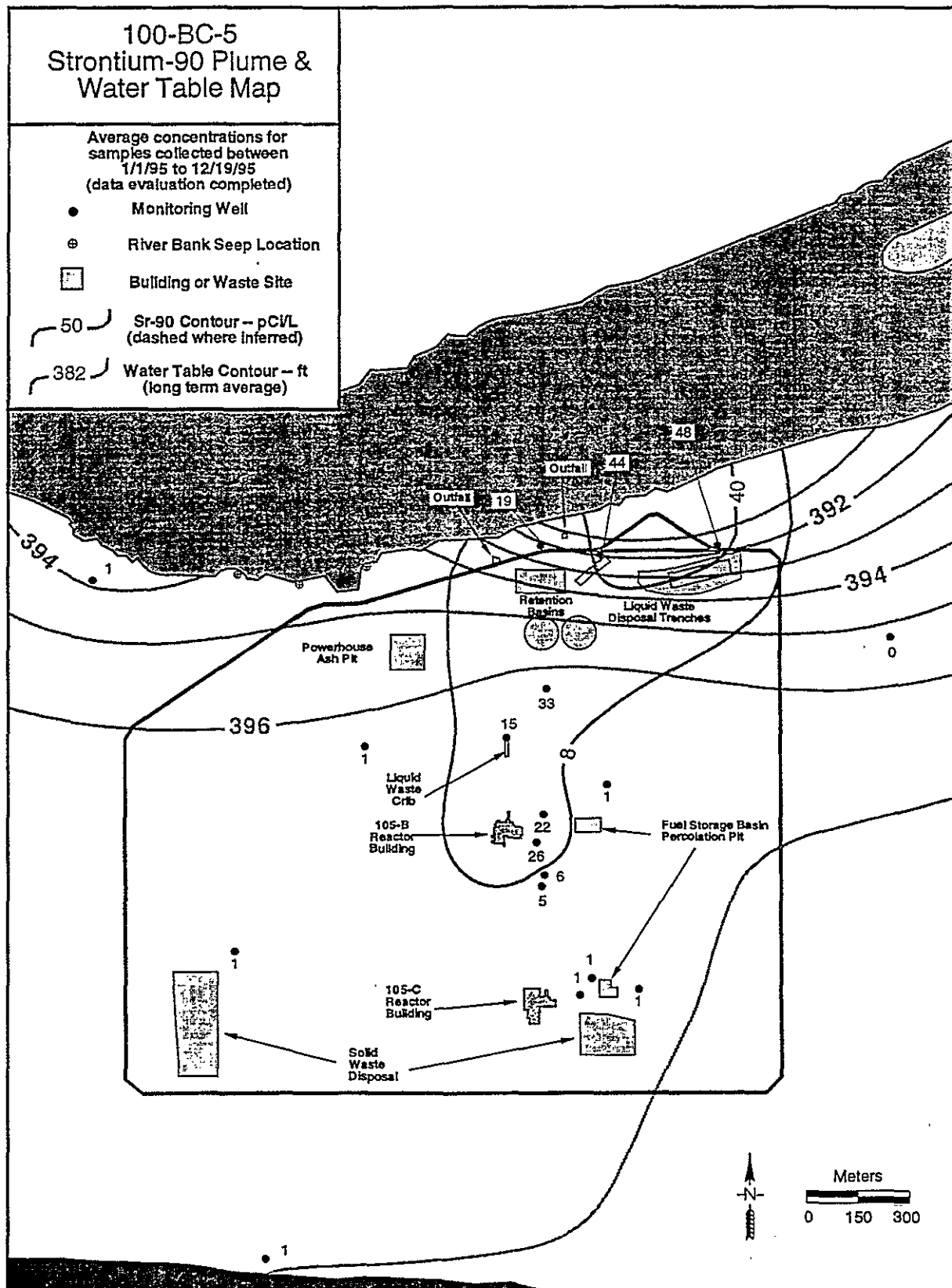


Figure 3-5. Strontium-90 Trends in Selected 100-B/C Area Near-River Wells

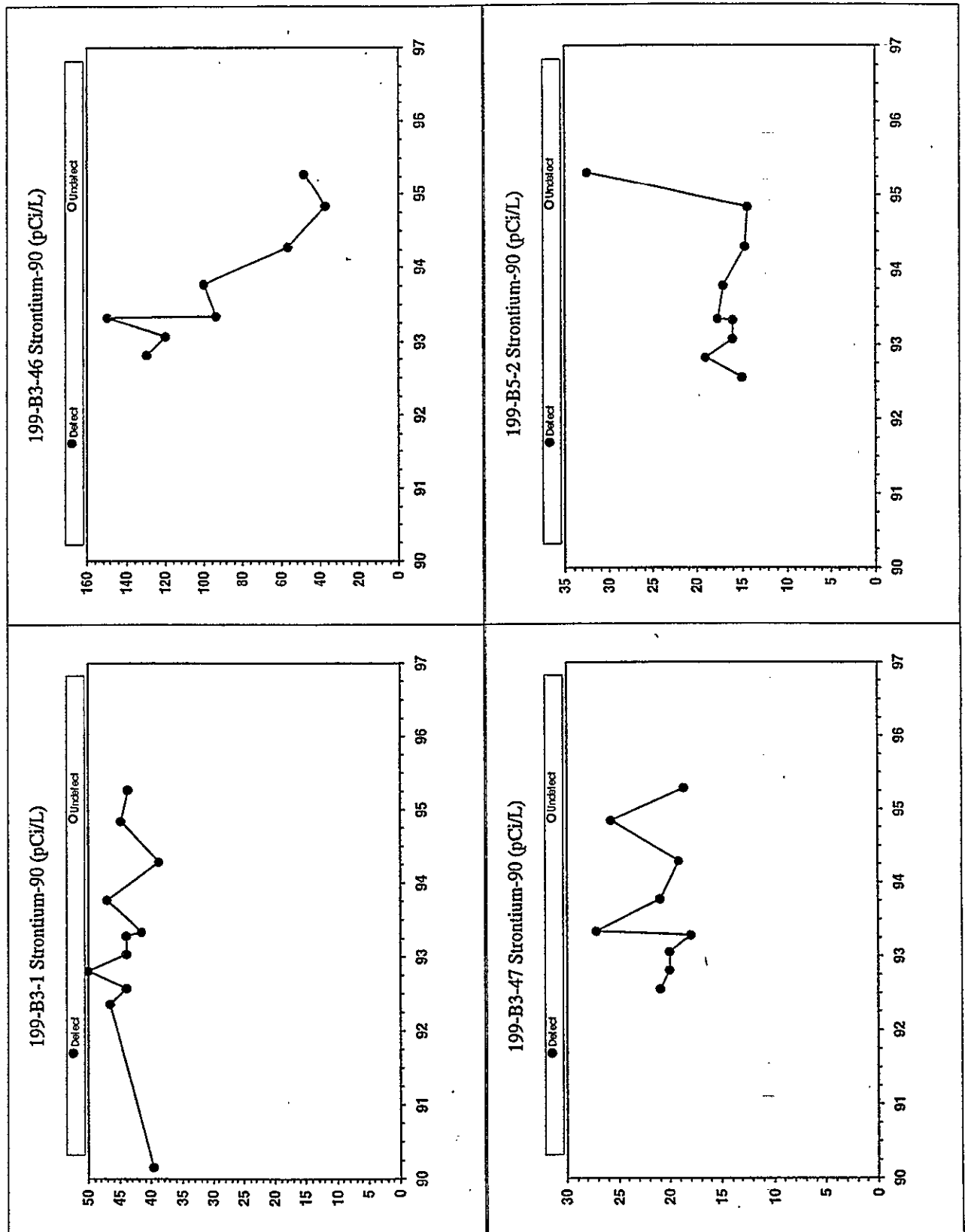
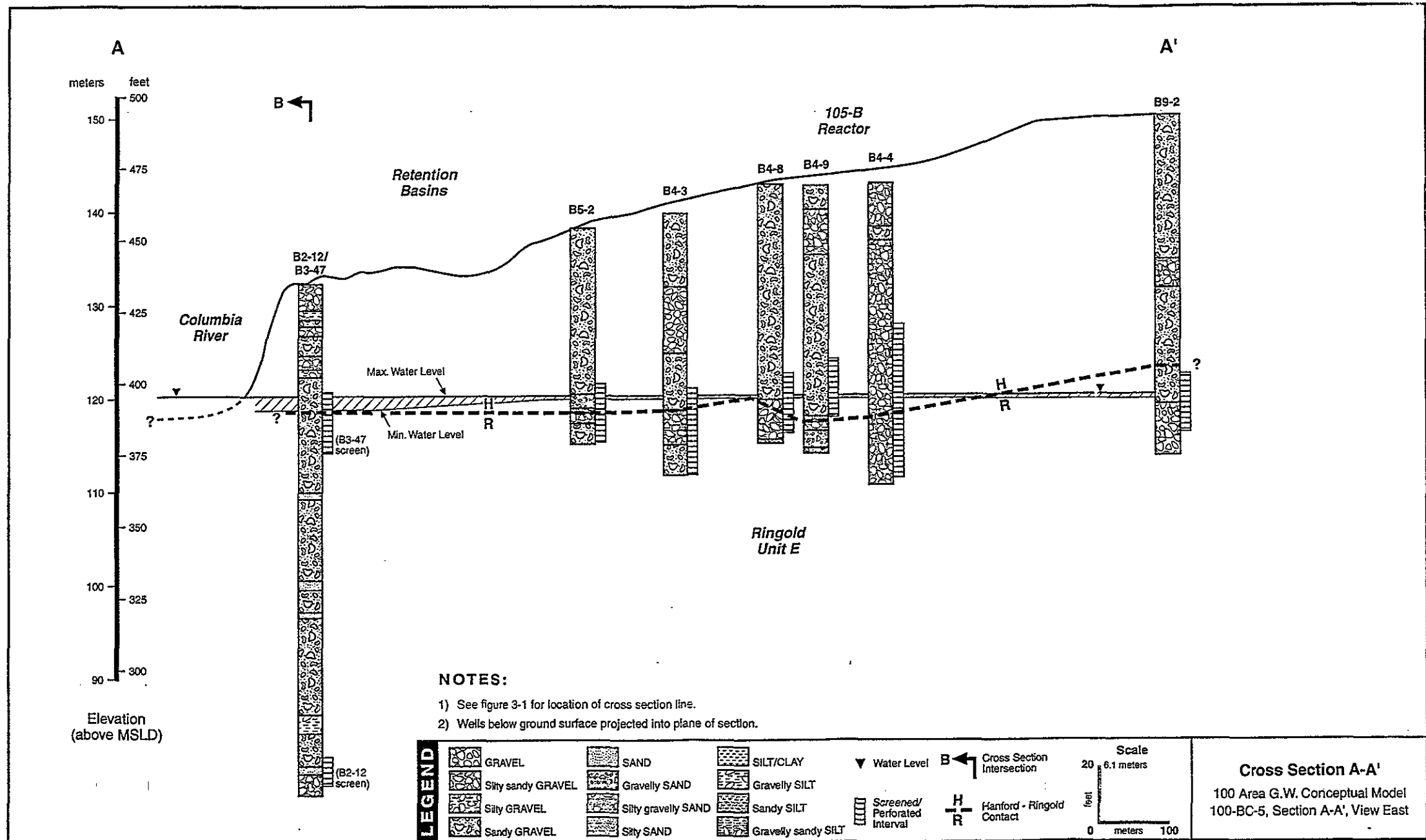


Figure 3-6. Cross Section (A-A') Perpendicular to the 100-B/C Area Shoreline



E9508109.2

Figure 3-7. Cross Section (B-B') Parallel to the 100-B/C Area Shoreline

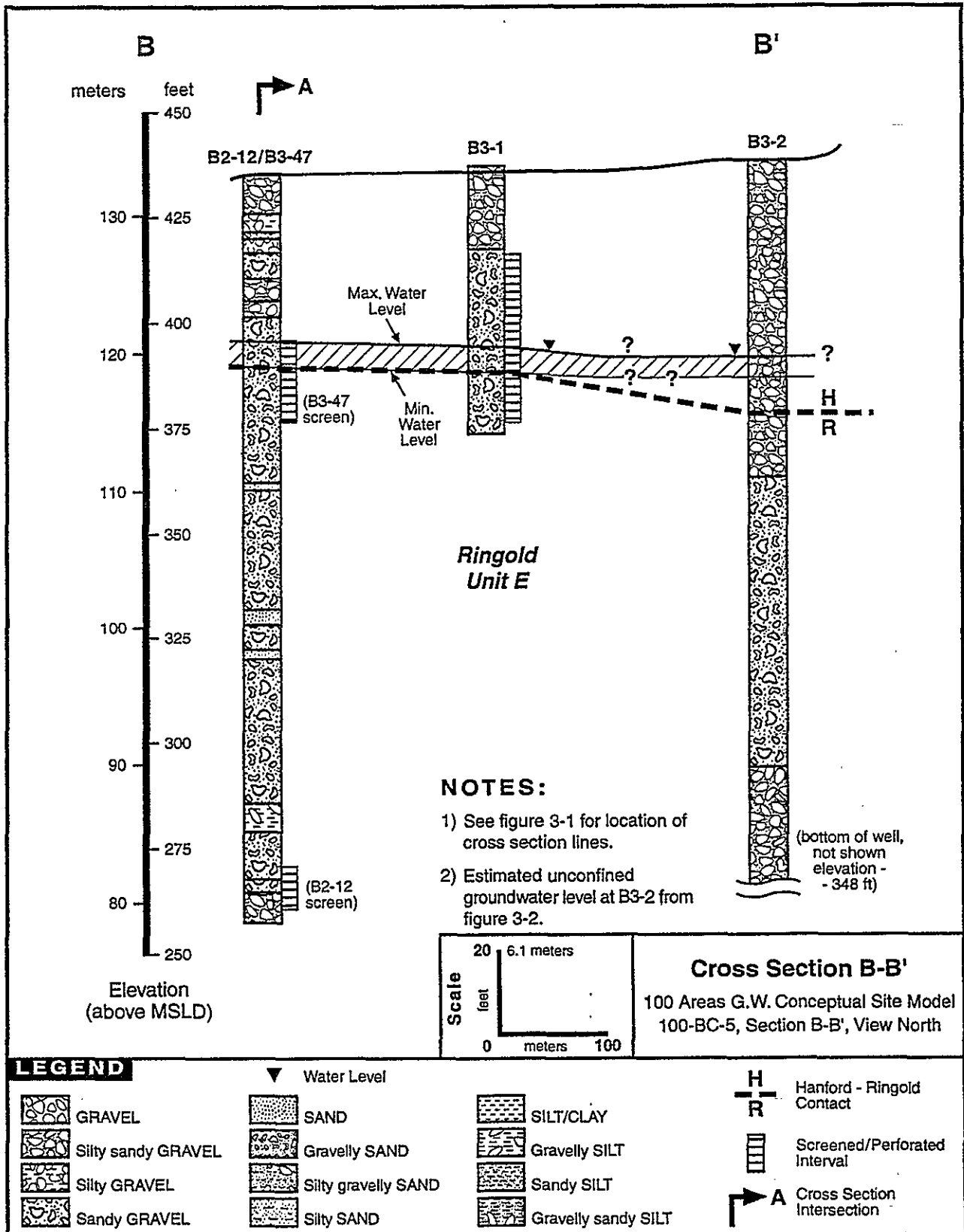
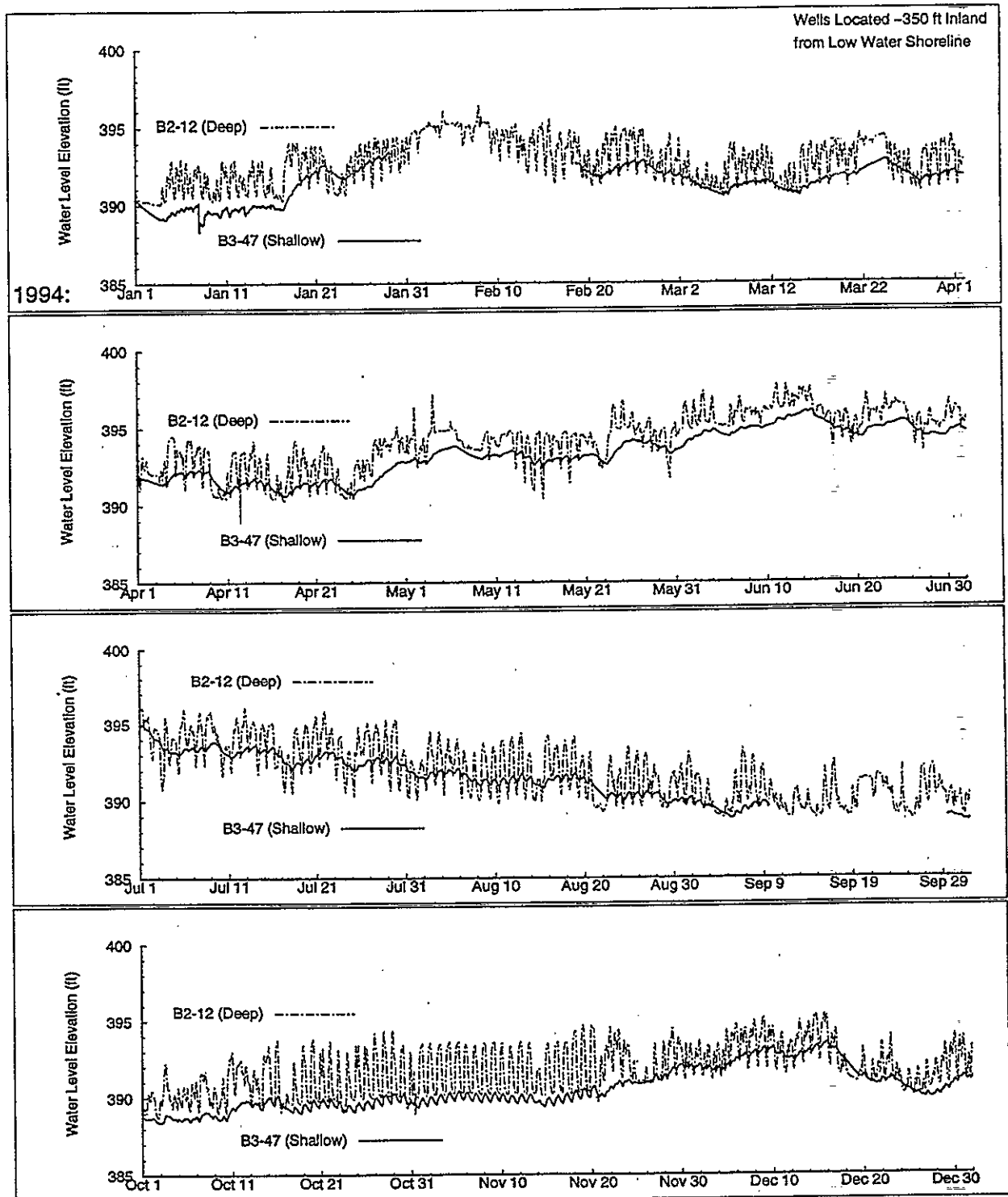


Figure 3-8. Hydrographs Illustrating Vertical Hydraulic Gradients in the 100-B/C Area



100-BC-5 Chemical Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
1,1,1-Trichloroethane	ppb	N	8	9	0	0.00	0.00	0.00	200	MCL	0	0	
Aluminum	ppb	N	21	50	13	23.80	286.00	64.72	50	SMCL	5	0	
Aluminum	ppb	Y	23	56	14	23.60	47.20	30.36	50	SMCL	0	0	6.86
Arsenic	ppb	N	21	50	41	1.10	4.80	3.21	50	MCL	0	0	
Arsenic	ppb	Y	21	50	45	0.94	10.30	3.38	50	MCL	0	0	8.06
Barium	ppb	N	21	50	50	10.20	75.40	30.86	1000	MCL	0	0	
Barium	ppb	Y	23	56	55	9.70	76.40	29.74	1000	MCL	0	0	91.57
Cadmium	ppb	N	21	50	0	0.00	0.00	0.00	10	MCL	0	0	
Cadmium	ppb	Y	23	56	5	2.40	3.70	3.08	10	MCL	0	0	3.07
Chloride	ppb	N	7	7	7	5100.00	12000.00	7371.43	250000	SMCL	0	0	16863.99
Chromium	ppb	N	21	50	44	4.10	80.70	21.86	50	MCL	4	0	
Chromium	ppb	Y	23	56	43	6.20	88.60	19.93	50	MCL	4	2	16.61
Copper	ppb	N	21	50	27	5.90	127.00	23.97	1300	MCL-P	0	0	
Copper	ppb	Y	23	56	26	5.40	31.10	15.36	1300	MCL-P	0	0	0.85
Fluoride	ppb	N	24	57	55	100.00	900.00	262.98	1400	MCL	0	0	904.00
Iron	ppb	N	21	50	43	23.90	558.00	142.70	300	SMCL	3	0	
Iron	ppb	Y	23	56	42	14.00	305.00	85.00	300	SMCL	1	1	415.86
Lead	ppb	N	21	50	6	1.20	8.60	3.17	50	MCL	0	0	
Lead	ppb	Y	21	50	8	0.84	5.90	2.67	50	MCL	0	0	3.47
Manganese	ppb	N	21	50	29	2.70	43.50	7.27	50	SMCL	0	0	
Manganese	ppb	Y	23	56	32	0.81	10.00	4.57	50	SMCL	0	0	40.11
Mercury	ppb	N	21	50	1	0.19	0.19	0.19	2	MCL	0	0	
Mercury	ppb	Y	21	50	2	0.11	0.14	0.13	2	MCL	0	0	0.00
Nickel	ppb	N	21	50	2	17.80	18.00	17.90	100	MCL	0	0	
Nickel	ppb	Y	23	56	0	0.00	0.00	0.00	100	MCL	0	0	2.19
Nitrate	ppb	N	7	7	5	5800.00	25000.00	16120.00	45000	MCL	0	0	31725.97
Selenium	ppb	N	21	50	29	0.93	3.10	1.81	10	MCL	0	0	
Selenium	ppb	Y	21	50	32	0.90	5.10	1.82	10	MCL	0	0	6.01
Silver	ppb	N	21	50	1	26.80	26.80	26.80	50	MCL	0	0	
Silver	ppb	Y	23	56	1	7.90	7.90	7.90	50	MCL	0	0	5.68
Sulfate	ppb	N	24	57	57	1500.00	71000.00	39535.09	250000	SMCL	0	0	84676.12
Trichloroethene	ppb	N	8	9	8	0.30	2.10	1.29	5	MCL	0	0	
Uranium	ppb	N	2	2	2	0.00	0.12	0.06	44	UMTR	0	0	9.28
Zinc	ppb	N	21	50	36	4.30	83.60	19.42	5000	SMCL	0	0	21.47
Zinc	ppb	Y	23	56	36	8.60	574.00	31.60	5000	SMCL	0	0	21.47

Table 3-1. Constituents Summary for the 100-BC-5 Operable Unit (Page 1 of 2)

100-BC-5 General Properties

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Dissolved Oxygen	mg/L	N	21	39	39	1.94	7.70	6.15			0	0	14935.41
pH Measurement	pH	N	25	101	101	6.30	8.85	7.84			0	0	8.07
Specific Conductance	umhos/cm	N	25	101	101	145.00	461.00	353.15			0	0	428.00
Temperature	Deg C	N	25	57	57	14.80	25.20	20.27			0	0	

100-BC-5 Radiological Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Carbon-14	pCi/L	N	21	41	3	3.96	17.00	8.39	2000	MCL	0	0	152.79
Gross Alpha	pCi/L	N	21	50	23	0.88	6.06	1.81	15	MCL	0	0	2.47
Gross Beta	pCi/L	N	21	50	50	3.83	140.00	35.94	50	MCL	15	8	7.44
Strontium-89/90	pCi/L	N	21	27	15	0.86	49.10	13.23			0	0	0.02
Strontium-90	pCi/L	N	22	25	14	0.02	48.40	16.03	8	MCL	7	7	0.02
Technetium-99	pCi/L	N	22	55	51	6.76	115.00	49.10	900	MCL	0	0	1.78
Tritium	pCi/L	N	25	57	53	377.12	27000.00	4608.10	20000	MCL	2	2	162.00

Data Source: Hanford Environmental Information System. Abbreviations: MCL = EPA maximum contaminant level (primary); MCL-P = EPA maximum contaminant level (proposed); SMCL = EPA maximum contaminant level (secondary); EPA 440/5-86-001-USEPA Freshwater Chronic Water Quality Criteria; and UMTR = Uranium Mining Tailings Reclamation. "Background Values" are provisional 90th percentile values taken from Hanford Site Background: Part 3, Groundwater (DOE/RL-96-91, Decisional Draft)

Table 3-1. Constituents Summary for the 100-BC-5 Operable Unit (Page 2 of 2)

Table 3-2. Constituents in 100-B/C Area Wells that Exceed Standards

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Chromium (50 $\mu\text{g/L}$)	199-B3-47 199-B5-1	51.7 88.6	350 1,580	Constituent of potential concern to ecological receptors in river environment.
Gross Beta (50 pCi/L)	199-B3-1 199-B3-46 199-B3-47 199-B4-1 199-B4-4 199-B4-9 199-B5-1 199-B5-2	140 114 70.4 57.4 76.2 68.6 76.6 54.9	550 800 350 2,100 3,160 2,900 1,580 1,685	Elevated gross beta probably reflects strontium-90.
Iron (300 $\mu\text{g/L}$)	199-B3-1	305	550	Iron is a common constituent of natural sediments; also commonly elevated in carbon-steel well casing.
Strontium-90 (8 pCi/L)	199-B3-1 199-B3-46 199-B3-47 199-B4-1 199-B4-4 199-B4-9 199-B5-2	43.7 48.4 18.6 14.8 26 22.3 32.5	550 800 350 2,100 3,160 2,900 1,685	Common in liquid effluent disposed to retention basins and trenches, and leakage from pipelines.
Tritium (20,000 pCi/L)	199-B5-2 699-65-72	27,000 20,300	1,685 (TBD)	Tritium may be residual from fuel storage basin water, and tritium production activities.

Table 3-3. 100-BC-1 Source Operable Unit High Priority Waste Sites

Waste Site	Physical Description of Waste Site	Former Waste Site Use	Contaminants of Potential Concern ¹
116-B-11 Retention Basin	Reinforced concrete retention basin. 143 m long x 70 m wide x 2 m deep.	Held cooling water effluent from 105-B Reactor for cooling/decay before release to the Columbia River. Large leaks of effluent to soil.	Am-241, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239, Ra-226, Sr-90, Th-228, U-238, antimony, chromium, lead, mercury
116-C-5 Retention Basin	Two circular steel tanks. 101 m diameter x 5 m deep.	Held cooling water effluent from 105-B and C Reactors for cooling/decay before release to the Columbia River. Large leaks of effluent to soil.	Am-241, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-238, Pu-239, Ra-226, Sr-90, Th-228, U-238, antimony, chromium, lead, mercury
116-B-1 Process Effluent Trench	Unlined trench. 108 m long x 9 m wide x 5 m deep.	Received high activity effluent produced by failed fuel elements, disposed effluent to the soil.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239, K-40, Sr-90, U-238, chromium
116-C-1 Process Effluent Trench	Unlined trench. 175 m long x 38 m wide x 7 m deep.	Received high activity effluent produced by failed fuel elements, disposed effluent to the soil.	Am-241, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239, Ra-226, Sr-90, Th-228, U-238, antimony, chromium, lead, mercury
116-B-13 and 116-B-14 Sludge Trenches	116-B-13, unlined trench, 15 m long x 15 m wide x 3 m deep. 116-B-14, unlined trench, 37 m long x 3 m wide x 3 m deep.	Received sludge from retention basins: sludge disposed to soil then trench backfilled.	Am-241, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239, Ra-226, Sr-90, U-238, antimony, chromium, lead, mercury
116-B-4 French Drain	Gravel filled pipe. 1 m diameter x 6 m deep.	Received contaminated spent acid from dummy decontamination facility; disposed effluent to soil.	Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-239, K-40, Th-228, barium.
² 116-B-12 Seal Pit Crib	Timber reinforced excavation filled with gravel, soil covered. 3 m long x 3 m wide x 3 m deep.	Received drainage from confinement seal system in 117-B building seal pits; disposed effluent to soil.	Th-228, arsenic, chromium
116-B-5 Crib	Concrete covered unlined crib containing boiler ash and gravel fill. 26 m long x 5 m wide x 4 m deep.	Received low-level effluent from contaminated maintenance shop and decontamination pad in 108-B building including tritium waste; disposed effluent to soil.	Cs-137, Co-60, Eu-152, Eu-154, H-3, barium, mercury
100-B/C Buried Process Effluent Pipelines	Buried process effluent pipelines. Total length = 6533 m pipe diameter - varies; leaks have occurred with known soil contamination.	Transported reactor cooling water from reactors to retention basins, outfall structures, and disposal trenches, contains contaminated sludge and scale.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-238, Pu-239, Sr-90, U-238

Am-241 = ²⁴¹americium
Cs-134 = ¹³⁴cesium
Cs-137 = ¹³⁷cesium
Co-60 = ⁶⁰cobalt
Eu-152 = ¹⁵²europium
Eu-154 = ¹⁵⁴europium
Eu-155 = ¹⁵⁵europium
H-3 = tritium

K-40 = ⁴⁰potassium
Ni-63 = ⁶³nickel
Pu-238 = ²³⁸plutonium
Pu-239/240 = ^{239/240}plutonium
Ra-226 = ²²⁶radium
Sr-90 = ⁹⁰strontium
Th-228 = ²²⁸thorium
U-238 = ²³⁸uranium

¹ The contaminants of potential concern were identified from the Qualitative Risk Assessment.

² Data not available for this site. Contaminants of potential concern identified based on analogous site 116-D-9 Crib.

Table 3-4. 100-BC-2 Source Operable Unit High Priority Waste Sites

Waste Site	Physical Description of Waste Site	Former Waste Site Use	Contaminants of Potential Concern ¹
116-C-2A Pluto Crib	Unlined earthen structure 6.9 m x 4.7 m x 1.5 m deep covered by 5.7 m non-contaminated soil fill.	Received effluent from the 116-C-2C Pluto Crib Sand Filter (see below).	Cs-137, Co-60, Eu-152, Pu-238, Pu-239/240, Ra-226, and Sr-90 are contaminants of potential concern for the Pluto Crib system, including the Pump Station and Sand Filter.
116-C-2B Pluto Crib Pump Station	Concrete-lined pit 3 m x 2.0 m x 8.9 m deep.	Pumped liquid wastes from the C reactor to the 116-C-2C Pluto Crib Sand Filter and 116-C-2A Pluto Crib.	
116-C-2C Pluto Crib Sand Filter	Open-bottomed concrete box 12.7 m x 5.5 m x 5.6 m deep.	Received cooling water from process tubes affected by fuel cladding failures and other C reactor effluents.	
118-B-1 Burial Ground	A series of lined and unlined trenches in a marked area 286 m x 82 m x 6.1 m deep	Contains solid wastes from 100 B and 100 N reactors including piping, equipment and trash.	Cs-137, Co-60, Eu-152, Eu-155
118-B-2 Burial Ground	Unlined trench 18.3 m x 9.1 m x 3.1 m deep. The site is assumed to be covered with 1.2 m of non-contaminated soil.	Contains dry waste from repair work on the 107-B basin and from minor construction work on the 115-B gas building conversion.	Co-60
118-B-3 Burial Ground	Unlined trench 107 m x 84 m x 6.1 m deep.	Contains reactor-generated solid waste and solid waste from effluent line modification; bulk of waste consists of cold-rolled steel pipe.	Co-60
118-B-4 Burial Ground	Six vertically buried metal culverts 1.8 m diameter x 4.6 m long covered by 1.2 m of non-contaminated soil. The burial ground is 15.2 m x 9.2 m x 5.8 m deep.	The culverts contain highly irradiated reactor fuel spacers.	Co-60
118-B-6 Burial Ground	Two vertically buried concrete pipes 1.8 m diameter x 5.5 m long covered by 1.2 m of non-contaminated soil.	The pipes contain tritium wastes and equipment from operation of a tritium separation program.	H-3
118-C-1 Burial Ground	A series of unlined trenches and pits in an area 155.4 m x 122 m x 6.1 m deep. Covered by 1.2 m non-contaminated soil.	Contains solid wastes from C reactor including piping, equipment and trash.	Cs-137, Co-60, Eu-152, Eu-155
118-C-2 Ball Storage Tank	Tank 1.8 m in diameter x 1.5 m tall buried beneath 0.6 m of non-contaminated soil.	Held highly irradiated boron steel and carbon steel balls for radioactive decay.	Co-60, Ni-63
118-C-4 Horizontal Control Rod Storage Cave	Above-ground storage structure 15.5 m x 1.0 m x 0.3 m high on a concrete pad. Covered by a 2.5 m mound of non-contaminated soil.	Held contaminated horizontal control rods for radioactive decay. May contain miscellaneous reactor facility components.	Co-60
128-C-1 Burning Pit	Unlined trench 77.8 m x 38.1 m x 6.1 m deep. Assumed to be covered with 1.2 m of non-contaminated soil cover.	Disposal of combustible materials (vegetation, office wastes, paint waste, chemical solvents), hardware, and non-contaminated miscellaneous equipment.	None identified
132-C-1 Reactor Exhaust Stack	Received exhaust air from C Reactor Building before 1960; exhaust air from 132-C-3 after 1960.	Stack 61 m high by 5.1 m diameter. Buried in 1985 in 9.1 m x 6 m x 5.5 m trench.	C-14, Cs-137, Co-60, Eu-152, Eu-154, H-3, Pu-238, Pu-239/240, and Sr-90
132-C-3 Exhaust Air Filter Building	Housed air flow control system and filters for C Reactor	18 m x 11.9 m x 10.7 m (2.4 m above grade). Completed demolition in 1988, buried in place.	C-14, Cs-137, Co-60, Eu-152, Eu-154, H-3, Pu-238, Pu-239/240, and Sr-90

Cs-137 = ¹³⁷cesium
 Co-60 = ⁶⁰cobalt
 Eu-152 = ¹⁵²europium
 Eu-155 = ¹⁵⁵europium
 Ni-63 = ⁶³Nickel

Pu-238 = ²³⁸plutonium
 Pu-239/240 = ^{239/240}plutonium
 Ra-226 = ²²⁶Radium
 Sr-90 = ⁹⁰strontium

¹ The contaminants of potential concern were identified from the qualitative risk assessment (QRA).

Table 3-5. Hydrogeologic Units Monitored by 100-B/C Area Wells

Well	Screened Interval Elevation; meters/(ft)	Hydrogeologic Unit	Average Ground- water Elevation meters/(ft)
199-B3-47	121.2- 114.8 m (397.7 - 376.6 ft)	Hanford formation/ Ringold Formation	119.3 m/(391.3ft)
199-B2-12	82.6-79.6 m (271.0 - 261.0 ft)	Ringold Formation overbank/paleosol	119.8 m/(393.0 ft)

Notes:

1. Groundwater elevations averaged from quarterly steel tape measurements conducted from 1-1-94 to 8-30-95.
2. Screened intervals from unpublished Westinghouse Hanford Company geologic well summaries.
3. Survey elevations from ICF Kaiser Hanford, 1992.



Table 3-6. Water Level and Specific Conductance in 100-B/C Area Wells (Page 1 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μS/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
Wells representative of conditions at or near the water table:											
199-B3-47	350	391.45	6.0	388.2	394.6	16	390	22	376	398	6
199-B3-1	550	391.92	5.9	389.1	395.0	15	457	89	429	518	6
199-B2-13	800	393.88	3.2	392.6	395.8	13	348	103	302	405	6
199-B3-46	800	391.64	5.5	389.2	394.7	14	385	32	370	402	5
199-B5-1	1,580	396.24	1.8	395.5	397.3	14	316	105	269	374	7
199-B5-2	1,685	396.26	1.9	395.4	397.3	13	411	155	361	516	7
199-B4-1	2,100	396.41	1.7	395.8	397.4	14	425	162	371	533	7
699-71-77	2,120	395.25	1.9	394.5	396.4	14	347	60	318	378	8
199-B4-3	2,150	396.40	1.1	395.9	396.9	2	406	28	392	420	2
699-72-73	2,343	395.70	1.4	395.1	396.5	14	319	44	306	350	10
199-B4-8	2,750	396.76	1.5	396.2	397.7	13	414	172	340	512	6
199-B4-9	2,900	396.86	1.5	396.3	397.8	15	407	177	345	522	7
199-B4-4	3,160	396.80	1.7	396.1	397.8	14	403	69	375	444	5
199-B4-6	3,500	396.87	1.5	396.2	397.8	12					
199-B4-7	3,500	396.53	0.0	396.5	396.5	1	374	33	357	390	4
199-B4-5	3,600	396.49	0.0	396.5	396.5	1	385	59	368	427	8
199-B8-6	3,830	396.88	1.7	396.2	397.9	15	319	137	286	423	6
199-B9-2	4,580	396.89	1.4	396.5	397.8	12	455	166	379	545	8
199-B9-1	4,730	396.89	0.6	396.6	397.1	3	385	171	310	481	7
199-B9-3	4,780	396.88	1.5	396.4	397.8	14	400	142	359	501	5
699-67-86	5,580	396.74	1.2	396.0	397.2	3	316	77	280	357	5
699-65-83	6,800	396.98	1.6	396.4	397.9	15	318	76	302	378	6

Table 3-6. Water Level and Specific Conductance in 100-B/C Area Wells (Page 2 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance ($\mu\text{S}/\text{cm}$)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
699-65-72	tbd	397.52	1.0	397.2	398.1	15	348	79	326	405	8
699-72-88	tbd	395.79	2.8	394.1	396.9	3	321	63	289	352	2
<i>Wells with open intervals significantly below the water table:</i>											
199-B2-12	350	392.97	5.8	390.3	396.1	15	279	108	242	350	6
199-B3-2p	tbd	tbd	tbd	tbd	tbd	tbd	170	51	146	197	3

Notes: Wells are listed in order of increasing distance from the river shoreline, as defined by low river stage. Data are representative of conditions between January 1, 1994 and August 30, 1995. Data source: HEIS.

Table 3-7. Aquifer Slug Test Results for 100-B/C Area Wells

Well	Hydraulic Conductivity cm/sec	Hydraulic Conductivity ft/day	Stratigraphic Unit Screened
199-B2-12	0.0007 to 0.002	2-6	Ringold Formation
199-B-2-13	0.018	50	Hanford formation
199-B3-46	0.005	15	Hanford/Ringold

Data from 100-BC-5 LFI report (DOE-RL, 1994a)

Table 3-8. Physical Properties for Aquifer Sediments in the 100-B/C Area

Well Number/ Depth Interval m (ft)	HEIS Sample Number	Specific Gravity g/cm ³	Bulk Density g/cm ³	Moisture Content %	K, Saturated cm/sec	Depth-to- Water m (ft)	Sediment Description
199-B2-12 2.6-2.9 m (8.6-9.6 ft)	B06118	2.63	1.96	1.81	0.00023	13.13 m (43.07 ft)	Silty, sandy GRAVEL
199-B2-12 7.9-8.2 m (26-27 ft)	B06119	2.67	2.03	1.43	0.00039	13.13 m (43.07 ft)	Silty, sandy GRAVEL
199-B2-12 24.5-24.8 m (80.5-81.5 ft)	B06120	2.63	2.05	6.11	0.00046	13.13 m (43.07 ft)	Slightly silty, sandy GRAVEL
199-B4-9 9.3-9.6 m (30.5-31.5 ft)	B06122	2.71	1.83	2.69	0.00042	21.82 m (71.58 ft)	Slightly silty, sandy GRAVEL
199-B4-9 21.2 - 21.5 m (69.5-70.5 ft)	B06123	2.73	2.12	10.08	0.00014	21.82 m (71.58 ft)	Slightly silty, sandy GRAVEL
199-B4-9 23.6- 23.9 m (77.5-78.5 ft)	B06125	2.72	2.15	7.61	0.00033	21.82 m (71.58 ft)	Sandy GRAVEL
199-B4-9 26.8-27.1 m (88-89 ft)	B06126	2.65	1.67	22.41	0.0021	21.82 m (71.58 ft)	SAND
199-B9-2 12.5-12.8 m (41-42 ft)	B06127	2.85	1.95	2.67	0.0018	29.73 m (97.54 ft)	Slightly silty, sandy GRAVEL
199-B9-2 23.8-24.1 m (78-79 ft)	B06128	2.81	1.92	2.52	not available	29.73 m (97.54 ft)	Slightly silty, sandy GRAVEL
199-B9-2 27.7-28.0 m (91-92 ft)	B06129	2.82	1.89	2.82	0.0025	29.73 m (97.54 ft)	Slightly sandy GRAVEL
199-B9-2 34.8-35.1 m (114-115 ft)	B06130	2.74	2.05	9.66	0.00006	29.73 m (97.54 ft)	Slightly sandy GRAVEL

4.0 100-KR-4 OPERABLE UNIT

The 100-KR-4 Operable Unit Contains the groundwater underlying the 100-K Area. It also includes adjacent areas where contaminated groundwater from the 100-K Area may pose a risk to human and ecological receptors. Examples of adjacent areas are the riverbed, where groundwater may upwell into sediments that form habitat for aquatic life, and locations where water seeps from the riverbank during low river conditions. Figure 4-1 is an index map for the 100-K Area that shows the locations of groundwater monitoring wells and facilities/waste sites discussed in the text.

The following sections describe contaminants of concern, their distribution, how they change with time, and the hydrogeologic framework through which they move.

4.1 CONTAMINANTS OF CONCERN

Contaminants of concern are chemical and radiological constituents that pose a risk to human and/or ecological receptors. Numerous regulatory requirements, such as the U.S. Environmental Protection Agency's (EPA) drinking water standards (40 CFR 141 "maximum contaminant levels" [MCL]) and ambient water quality criteria (AWQC) for protection of freshwater aquatic organisms, help identify which constituents are of concern.

A limited field investigation (LFI) for the 100-KR-4 Operable Unit identified contaminants of potential concern based on a limited set of data collected in 1992 and 1993. These contaminants were used in a qualitative risk assessment, the results of which included recommendations regarding interim remedial measures (IRM). The contaminants of concern, conclusions, and recommendations contained in the LFI report (DOE-RL, 1994b) are as follows:

Operable Unit	Human Health Risk	Ecological Risk	LFI Conclusion and Recommendation
100-KR-4	Arsenic Carbon-14 Chromium Nitrate Tritium	Chromium Carbon-14 Iron Lead Silver Zinc	An IRM is not indicated on the basis of human health or ecological risk. Continue on IRM pathway, however. Note: Subsequent analysis of data concluded that ecological risk from chromium warranted interim remedial measures.

Source: Limited Field Investigation Report (DOE-RL, 1994b)

These contaminants of concern continue to be tracked primarily by semiannual sampling of wells since the LFI phase of the remedial investigation/feasibility study (RI/FS). As sufficient information becomes available to demonstrate that a contaminant is no longer of concern with

respect to human health and ecological risk, it is typically removed from the monitoring schedule. However, data for some discontinued contaminants of concern may continue to accumulate, because the constituent is part of a grouped analysis (e.g., analysis of metals by inductively coupled plasma (ICP)).

Characterization and focused feasibility study (FFS) activities that occurred during the final phases of the LFI resulted in a revised assessment of ecological risk because of hexavalent chromium in groundwater near the Columbia River. This led to a decision to proceed with interim remedial measures (IRM) to address chromium contamination (DOE-RL, 1995b and EPA, 1996a). A remedial design/remedial action (RD/RA) work plan (DOE-RL, 1996) describes this IRM, which includes the 100-HR-3 Operable Unit also.

4.1.1 Summary of Current Groundwater Contamination Levels

Table 4-1 presents recently observed concentrations for contaminants of potential concern identified during the LFI, along with concentrations for additional waste and water quality indicators. This table includes all results contained in the Hanford Environmental Information System (HEIS) database for sampling more recent than January 1, 1995 (generally inclusive of sampling conducted through January 1996). Semiannual sampling has been the norm since the last half of 1994, so this summary is generally based on two or three sampling events per well.

Initial data evaluation processing has been completed on the entire data set summarized in Table 4-1 (i.e., assigning common units, removing duplicate entries, and correcting known errors in reported results). The full data evaluation process has been completed for chromium, nitrate, strontium-90, tritium, and specific conductance (see Ford and Denslow, 1996 for a description of the data evaluation process for data extracted from HEIS). Some values in Table 4-1 for constituents other than the five listed above may be less representative of aquifer conditions than values for fully evaluated constituents.

The list of constituents that currently exceed regulatory standards is similar to the list of contaminants of potential concern identified during the LFI, with several exceptions. Carbon-14, chromium, iron, nitrate, and tritium remain above standards; arsenic, lead, silver, and zinc no longer exceed standards. Additional constituents that exceed standards are aluminum, manganese, nickel, selenium, strontium-90 (and gross beta), and trichloroethene. Of these constituents, strontium-90 appears to be the only new contaminant of concern, based on the significantly elevated concentration in well 199-K-109A.

Table 4-2 identifies the 100-K Area wells in which various constituents that are included in Table 4-1 exceed standards. Several wells in which standards are exceeded appear to be isolated occurrences and are not deemed indicative of widespread groundwater contamination (e.g., those for aluminum, manganese, nickel, selenium, and trichloroethene).

4.1.2 Sources for Contamination in Groundwater

The principal surface facilities associated with liquid waste disposal to the soil column are shown in Figure 4-1. A detailed description of these waste-generating facilities is contained in the 100-K Area Technical Baseline Report (Carpenter and Coté, 1994). A description of how the plutonium production reactors operated is presented in the "Hazards Summary Report" for the production reactor plants (General Electric, 1963). Both documents provide comprehensive background material for interpreting the origin of groundwater contamination. The source information in the following summary is derived from those documents, unless otherwise cited.

4.1.2.1 100-K Mile Long Trench. This facility is the primary source for the chromium plume being targeted by the IRM. It is located to the northeast of the 105-KE reactor facilities and, in its original configuration, is approximately 4,000 ft long by 45 ft wide by 15 ft deep. It was designed as a soil column liquid effluent disposal facility and operated between 1955 and 1971. It is the largest radioactive liquid waste trench in the 100 Area and has received significant quantities of chemical wastes (e.g., 300,000 kg of sodium dichromate), radionuclides (estimated at 2,100 Ci), and occasional solid waste, such as contaminated storage tanks and equipment.

Solutions containing chromium that were discharged to the trench were primarily decontamination solutions and leakage of routine coolant water from the 107-K retention basin and floor drains in the 105-KE and -KW reactor buildings. Solutions contributing the greatest amount of radionuclides were decontamination solutions, shielding water from the fuel storage basins, and coolant water containing debris from fuel element failures.

Leakage from the retention basins, via faulty valves and piping that leads to the 100-K Mile Long Trench, has been estimated to be 10,000 to 20,000 gpm, which is sufficient to create a mound on the underlying water table. The mound was on the order of 20 ft higher than the natural water table and caused an increase in the rate of groundwater flow to the river, to perhaps 10 ft/d (Brown, 1963). The retention basins' source was greatly reduced after 1963, when coolant water was rerouted to the river directly, thus bypassing the faulting valving.

After 1963, the mound dissipated, and it is probable that chromium remained with the residual moisture in the normally unsaturated part of the soil column. This residual chromium may continue to migrate slowly downward for many years, contributing a small but continual supply to groundwater.

4.1.2.2 Coolant water retention basins. Coolant for the 105-KE and 105-KW reactors was piped from the reactors to the 107-KE and 107-KW retention basins, which were steel tanks located near the Columbia River. Thermal cooling and decay of short-lived radionuclides occurred in these tanks. The coolant was then discharged into the river via large-diameter outfall pipes. Significant leakage of coolant water occurred from the retention basins to the ground, as well as to the 100-K Mile Long Trench via faulty valves and associated piping.

4.1.2.3 Summary of source operable unit high-priority waste sites. As part of source operable unit investigations, summaries of waste sites have been prepared that list known waste

sites, describe their characteristics, and indicate the contaminants of concern associated with each site. These summaries were originally presented in the proposed plans for the 100-KR-1 and 100-KR-2 Operable Units (DOE-RL, 1995e and DOE-RL, 1995f, and are included here as Tables 4-3 and 4-4.

4.1.2.4 Summary of liquid waste sites that received chromium. Table 4-5 lists known liquid waste disposal sites within the 100-K Area. The table has been assembled from available information gathered during the RI/FS. It draws heavily on information contained in the 100-K Area Technical Baseline Report (Carpenter and Coté, 1994).

4.2 CONTAMINANT DISTRIBUTION MAPS AND TREND CHARTS

To illustrate the current distribution of contamination in groundwater, data obtained since January 1, 1995, for chromium, tritium, carbon-14, strontium-90, and nitrate concentrations have been plotted on maps. The concentrations plotted are average values for data from HEIS that have undergone the full data evaluation process (Ford and Denslow, 1996). This process is intended to produce concentration values that accurately represent aquifer conditions. The average values presented do not include results considered nonrepresentative ("outliers") by the data evaluator. Chromium results are for filtered samples, since these data provide the best indicator of chromium that is dispersed by groundwater flow.

The maps include water table contours for long-term average elevations, as estimated by measurements for the period January 1, 1994, through August 30, 1995. Groundwater flow is generally oriented perpendicular to the contour lines. The rate of flow is highest where the contours are closest together.

4.2.1 Chromium Contamination

Chromium is elevated in three regions of the 100-K Area (Figure 4-2). The first and most widespread occurrence is between the 100-K Mile Long Trench, which is northeast of the reactors, and the Columbia River. This plume is being addressed by an interim remedial measure that includes a well extraction/reinjection network and water treatment system (DOE-RL, 1996). The plume's extent is described by a contour line drawn for 22 $\mu\text{g/L}$, a target concentration believed protective of aquatic organisms in the river environment (EPA, 1996a). The southeastern extent of the plume is uncertain, since there is no monitoring well coverage in this area. Chromium concentration data for this area should become available during fall 1996, as new wells are installed for reinjecting treated water during the IRM.

Concentrations in wells that define the IRM target plume are shown in Figures 4-3 and 4-4. With the exception of two wells at the southwest edge of the plume (199-K-32A and 199-K-18), concentrations are constant or decreasing. Slight increases are noted in wells 199-K-32A and 199-K-18 (Figure 4-4), although concentrations are below or near the MCL of 50 $\mu\text{g/L}$. There is no obvious explanation for these increasing trends. Chromium appears to be limited to the upper

portions of the unconfined aquifer, as revealed by concentrations in wells 199-K-32A (completed at the water table) and 199-K-32B (completed 115 ft below the water table) (Figure 4-4).

The second region of elevated chromium is centered on well 199-K-36, which is located at the southern end of the K-East water treatment basins (Figure 4-2). (Note: these basins are currently operated as fish rearing ponds). The most recent results from well 199-K-36 are the highest observed values in the 100 Area for chromium analyses of filtered samples. The suspected source for this hot spot is leakage or spillage of sodium dichromate stock solution, which was stored in the immediate area (see Table 4-5, waste site 120-KE-6). A widespread chromium plume is not indicated by samples from monitoring wells downgradient of this hot spot.

The third region of elevated chromium is centered on the 105-KE reactor building (Figure 4-2). There, two wells (199-K-107A and -108A) show significantly elevated concentrations. Trends for these relatively new wells are shown in Figure 4-5. While the trends are somewhat erratic, groundwater contamination in the area is indicated by the multiple sampling-round results. Suspected sources for this chromium is decontamination solution disposal to miscellaneous facilities near the reactor building.

4.2.2 Tritium Contamination

Tritium concentrations in 100-K Area wells are shown in Figure 4-6. Two hot-spot areas are defined--one near the 105-KW reactor and a second near the 105-KE reactor. Concentrations in several wells greatly exceed the 20,000 pCi/L MCL standard (see Tables 4-1 and 4-2). Tritium trends in wells near the 105-KW reactor (199-K-33 and 199-K-106A) and 105-KE reactor (199-K-30 and 199-K-32A) are shown in Figure 4-7.

The suspected primary source for tritium contamination is reactor atmosphere gas condensate that was disposed to french drains located immediately east of each reactor building. These french drains are designated 116-KW-1 and 166-KE-1 "condensate cribs" in Table 4-4. Gas condensate disposal to these facilities, which ended in 1971, contained tritium and carbon-14.

A second potential source for tritium is leakage from the fuel storage basins associated with each reactor. Both fuel storage basins are currently operating, and both contain water for shielding that contains high concentrations of tritium and other radionuclides. Enhanced monitoring of the fuel storage basins by Westinghouse Hanford Company (WHC) started in 1994, with the results described in periodic reports (Peterson, 1994a; Johnson et al., 1995; Johnson and Evelo, 1995). Tritium is currently monitored monthly by WHC in wells adjacent to the fuel storage basins.

While some tritium may be attributed to 105-KE fuel storage basin leakage, it is unlikely that all tritium in groundwater is from that source. Downward movement of residual tritium and carbon-14 through the soil column underlying the 116-KW-1 and 116-KE-1 condensate cribs may be continuing. There is evidence to indicate that downward movement is accelerated by infiltration from the surface (Johnson and Evelo, 1995). Their report points out that precipitation, including runoff from buildings and roadways, collects in the low spots over the cribs.

4.2.3 Carbon-14 Contamination

Carbon-14 is elevated above the 2,000 pCi/L MCL standard in two locations (Figure 4-8). The hot spots are associated with reactor-atmosphere gas-condensate disposal to the soil column via french drains, located immediately east of each reactor building. These waste sites are listed as the 116-KE-1 and 116-KW-1 condensate cribs in Table 4-4. An additional contaminant, tritium, was also a component of the gas-condensate waste stream and is distributed similarly to carbon-14. The groundwater plume from these waste facilities appears more extensive near the 105-KW reactor than the 105-KE reactor. The possible driving mechanisms for maintaining the contamination levels for carbon-14 and tritium from the condensate cribs is described above in Section 4.2.2.

Carbon-14 concentration trends in wells near the 105-KW reactor are shown in Figure 4-9. An increasing trend is present in well 199-K-33, which is located farther downgradient from the suspected source than other wells. Well 199-K-34, located nearer the source, shows a decreasing trend. This pattern is consistent with the idea that a plume of groundwater containing carbon-14 has migrated downgradient towards the river, and that the highest concentrations of that water mass have migrated away from the condensate crib source. However, the trend in a relatively new well located immediately downgradient of the crib (well 199-K-106A) is erratic and indicates much high contamination levels that the wells further downgradient. A possible explanation is presented in Section 4.2.2 under the tritium discussion.

Near the 105-KE reactor, carbon-14 is elevated in well 199-K-30, which is an analog to well 199-K-106A near the 105-KW reactor (Figure 4-10). Wells downgradient of 199-K-30 do not show evidence of a plume comparable to the plume at the 105-KW reactor.

4.2.4 Strontium-90 Contamination

Strontium-90 concentrations in 100-K Area wells are shown in Figure 4-11. Strontium-90 is slightly elevated above the 8 pCi/L MCL standard in three wells included in the network for the IRM associated with chromium contamination (wells 199-K-19, K-20, and K-21). The source for this strontium-90 is the 100-K Mile Long Trench. Concentration trends for these wells are shown in Figure 4-12. Concentrations for most wells are remaining constant, or decreasing slightly, with the exception of well 199-K-22, which shows an erratic trend. However, most data for that well are below the MCL standard.

Two strontium-90 hot spots are suggested on the concentration map (Figure 4-11). One involves two wells (199-K-34 and 199-K-107A) located adjacent to the 105-KW reactor, and a second involves well 199-K-109A, which is located near the 105-KE reactor. Trend plots for these wells are shown in Figure 4-13. Facilities associated with the reactor buildings' fuel storage basins (Johnson and Evelo, 1995) are the suspected source for these hot spots. The facilities include sub-basin drainage systems, overflow drains, and a drain field for soil column disposal of effluents from the basin.

The soil column in the vicinity of these three wells is very likely to contain radionuclides from past operations. When moisture in amounts greater than normal is added to the soil column, stored radionuclides, such as strontium-90, may be remobilized downward. Mechanisms to increase moisture in the soil column include unusually high precipitation events, ponding of runoff from roads and buildings, and leakage of underground utility water lines--all of which may be implicated in accelerating the downward movement of radionuclides to groundwater (Johnson and Evelo, 1995).

4.2.5 Nitrate Contamination

The distribution of nitrate in 100-K Area groundwater is shown in Figure 4-14. Two areas contain nitrate in concentrations that exceed the MCL standard of 45,000 $\mu\text{g/L}$. The first appears to extend from the vicinity of the 105-KW reactor building toward the river. The second area is more difficult to define by existing well coverage, but appears to be associated with waste sites near the 105-KE reactor building and possibly the 100-K Mile Long Trench. Well-defined sources for nitrate plumes are not readily apparent.

4.3 HYDROGEOLOGY

This section describes the framework through which contamination may be transported by groundwater movement. The lithologies of the stratigraphic units, the saturated and unsaturated zones, and physical properties of the various hydrostratigraphic units are described in the following sections.

4.3.1 Hanford and Ringold Stratigraphic Units

The most important stratigraphic units underlying the 100-KR-4 reactors are the Hanford formation and the upper units of the Ringold Formation. Figures 4-15 and 4-16 are geologic cross sections oriented parallel to groundwater flow and the Columbia River channel. Figure 4-17 is a cross section oriented approximately perpendicular to the Columbia River. These cross sections show the contact between engineered fill material and the Hanford formation, the Hanford-Ringold contact, and the top of the Ringold upper mud. They also graphically display sediments recovered during drilling of the groundwater monitoring wells and show the range in depth to groundwater from January 1, 1994, to August 30, 1995. The 100-K Area location map (Figure 4-1) shows the location of the three geologic cross sections constructed through the 100-KR-4 groundwater operable unit.

Imported gravel-sized fill is present up to a depth of 10 m (30 ft) in the 199-K-33 area. Fill material was placed during reactor construction.

4.3.1.1 Hanford formation. The Hanford formation is absent from the 100-KR-4 stratigraphic column in wells starting below an elevation of about 130 m (425 ft). The Hanford formation in the 100-KR-4 area is dominated by sandy gravel and silty sandy gravel with local gravelly sand interbeds (see Figure 4-15, section C-C'). A maximum thickness of 12.8 m (42 ft) is present in

199-K-36 in the reactor area. The Hanford formation thickens to over 36 m (120 ft) in well 699-73-61, which is about 1 km to the southeast of 199-K-36.

4.3.1.2 Ringold Formation. The Ringold Formation in the 100-K Reactor Area includes both the Unit E and Unit C paleosol overbank deposits. Well 199-K-32B was drilled through the 35.7 m (117 ft) of Unit E to the contact with the overbank deposits. This was the only well in the reactor area to completely penetrate Unit E. Unit E is composed largely of sandy gravel and gravelly sand beds, with minor sand and silty interbeds. The maximum drilled thickness was 41 m (136 ft) in 199-K-10 (Lindberg, 1993b).

Well 199-K-32B penetrated about 12 m (40 ft) into the overbank and paleosol deposits. These deposits were composed of silt with sandy interbeds. Lindberg (1993b) indicates that this unit is about 64 m (209 ft) thick and composed of three strata. The upper stratum, penetrated by 199-K-32B, is about 29 m (96 ft) thick and is predominantly silt.

4.3.2 Vadose Zone and Uppermost Aquifer

The vadose zone ranges in thickness from approximately 28.6 m (94 ft) in 199-K-36 to 7.6 m (25 ft) in 199-K-18 near the Columbia River (see Figures 4-15, 4-16, and 4-17). These figures show that the water table and unconfined aquifer are located in the Ringold Formation Unit E. Therefore, it follows that the base of the unconfined aquifer is the Ringold Unit C overbank/paleosol deposits. The saturated thickness of the uppermost aquifer in 199-K-32B was 27.4 m (90 ft), based on average groundwater elevations from January 1, 1994, to August 30, 1995. This is the only well to completely penetrate Unit E in the reactor area.

The 100-KR-4 Operable Unit geologic sections (Figures 4-15, 4-16, and 4-17) also show maximum and minimum groundwater elevations for the top of the uppermost aquifer, for depth-to-water measurements from January 1, 1994 to August 30, 1995. Wells near the Columbia River, such as 199-K-32A, range up to 2.22 m (7.3 ft) in groundwater elevation, while wells inland, such as 199-K-35, vary as little as 0.34 m (1.1 ft). The range in groundwater elevation near the river is largely due to the effect of river stage. The flow direction is to the northwest, with a gradient of 0.003.

A vertical (upward) hydraulic gradient between the Ringold Formation overbank/paleosol deposits and Unit E is clearly present on hydrographs of transducer data from 199-K-32A and 199-K-32B (Figure 4-18). Average groundwater elevations in the 199-K-32B well, screened in the Ringold overbank/paleosol deposits, are about 2.4 m (8.2 ft) higher than in 199-K-32A, screened in the Ringold Formation Unit E (Table 4-6). The vertical gradient, measured between the midpoint of the two screened intervals, is about 0.08.

4.3.3 River Influence on Monitoring Wells

Water level elevations and specific conductance are used to qualitatively evaluate the influence the river has on monitoring wells. Table 4-7 summarizes water level elevations and specific conductance for each 100-K Area well and shows the well's distance inland from the river's low-

water shoreline. The wells are separated into two groups in the table: (1) those that have screened or perforated open intervals that include the water table and (2) those that are open at depths in the aquifer well below the water table.

Data for Table 4-7 were extracted from HEIS in the form of depth-to-water measurements. These values were combined with recent top-of-casing surveys, using either results from an extensive 1993 U.S. Army Corps of Engineers survey, or, when Corps data are not available, results from a recent ICF Kaiser Hanford, Inc., survey. These surveys are referenced to baseline monuments, the locations of which were re-established by the Corps in 1993. All data are referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

The average water level elevation is for data obtained during the period from January 1, 1994, through August 30, 1995. This average represents long-term conditions over slightly more than a seasonal cycle. The range between minimum and maximum water level elevations provides a measure of the degree to which river stage fluctuations influence the well. The range is also influenced by the degree to which the aquifer segment intercepted by the well is confined. In response to river fluctuations, more confined segments produce greater changes in well water levels.

Values for specific conductance are also included in Table 4-7. Specific conductance, which varies with the amount of dissolved salts in the groundwater, can be used to identify water of various origins. River water is typically in the range of 120 to 140 $\mu\text{S}/\text{cm}$. Groundwater from the Hanford gravels is approximately 400 $\mu\text{S}/\text{cm}$, while water from the Ringold Formation appears to be approximately 300 $\mu\text{S}/\text{cm}$, although data to support the latter are limited. Given these contrasts, specific conductance is useful in helping to describe the interaction between river water and groundwater. However, where contamination is present, specific conductance may vary over a wide range, thus reducing its usefulness as a mixing indicator for natural waters.

4.3.4 Aquifer Properties

Slug tests were conducted in seven wells in the 100-K Area during the LFI. The results were analyzed in accordance with Bouwer and Rice (1976) and Bouwer (1989). Table 4-8 includes hydraulic conductivities from slug test data collected from wells drilled during the LFI and screened in the Ringold Formation Unit E (DOE-RL, 1994b). Hydraulic conductivities varied from 0.0067 cm/sec (19 ft/d) in 199-K-33 to 0.051 cm/sec (145 ft/d) in 199-K-37. The estimated geometric mean of hydraulic conductivity was 0.0071 cm/sec (20 ft/day), estimated from well-performance testing of 199-K-18, 199-K-19, 199-K-20, 199-K-21, 199-K-22, and 199-K-37. The testing was part of interim remedial measures design activities by the Environmental Restoration Contractor (ERC) in 1995 (DOE-RL, 1996).

4.3.5 Physical Properties of Aquifer Materials

Table 4-9 is a summary of physical-properties testing conducted on nine samples that were collected in the Hanford formation from wells 199-K-106A, 199-K-107A, 199-K-108A, 199-K-109A, 199-K-110A, and 199-K-111A. Samples are classified by hydrogeologic designation (e.g., vadose), sediment description, and stratigraphic unit.

Figure 4-1. Well Locations and Principal Facilities in the 100-KR-4 Operable Unit

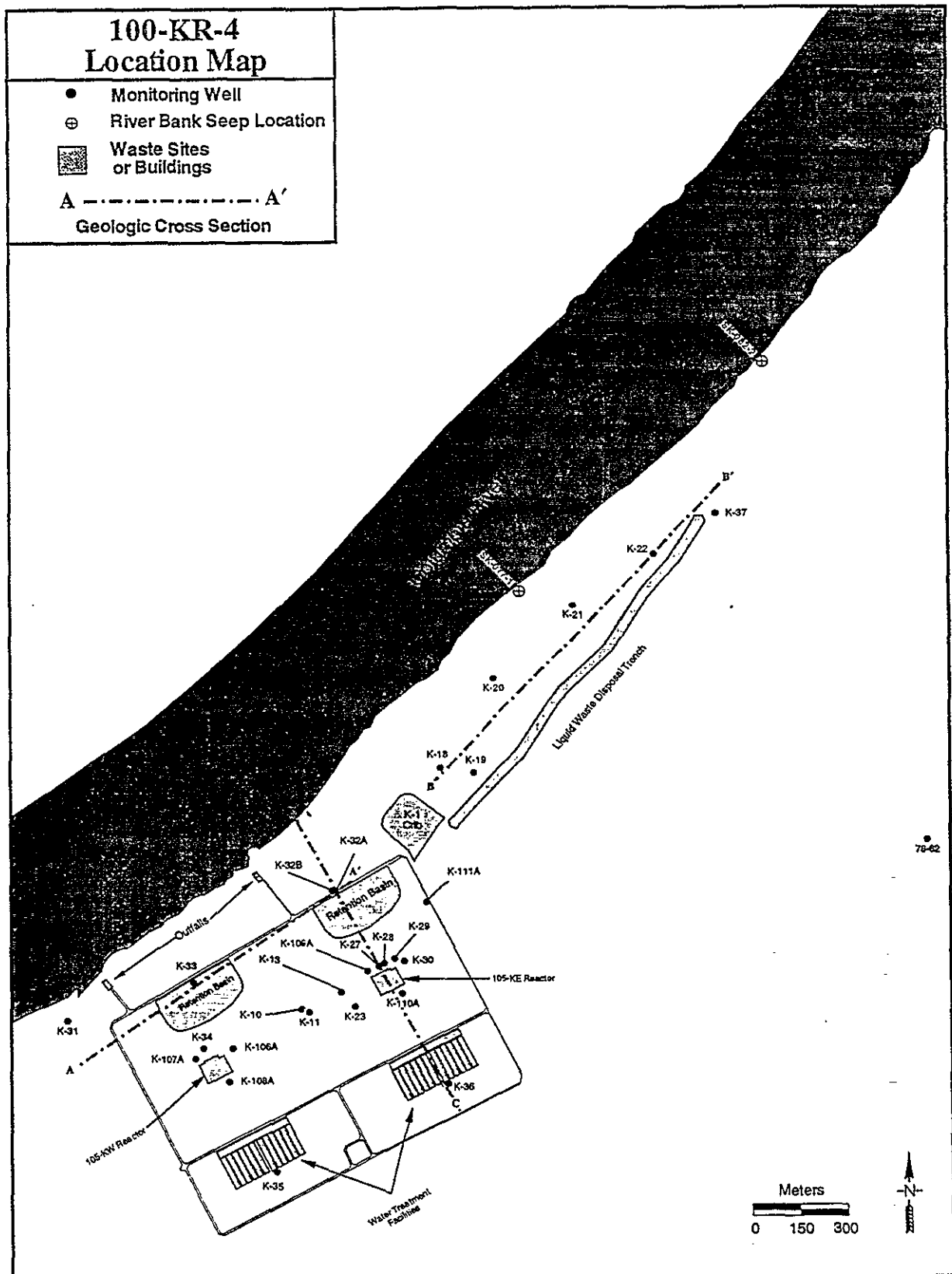


Figure 4-2. Chromium Distribution in the 100-K Area

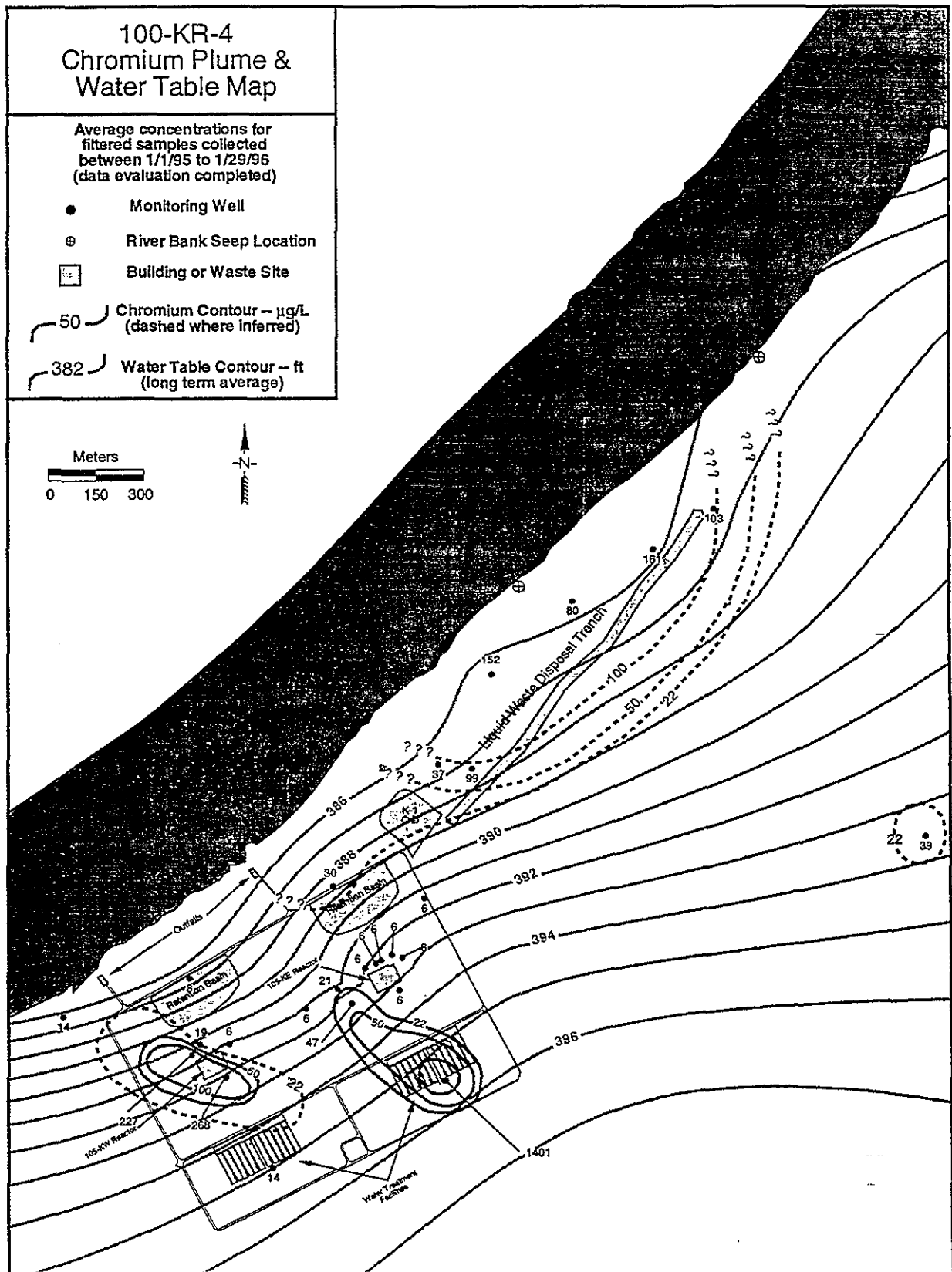


Figure 4-3. Chromium Trends in Selected 100-K Area IRM Network Wells

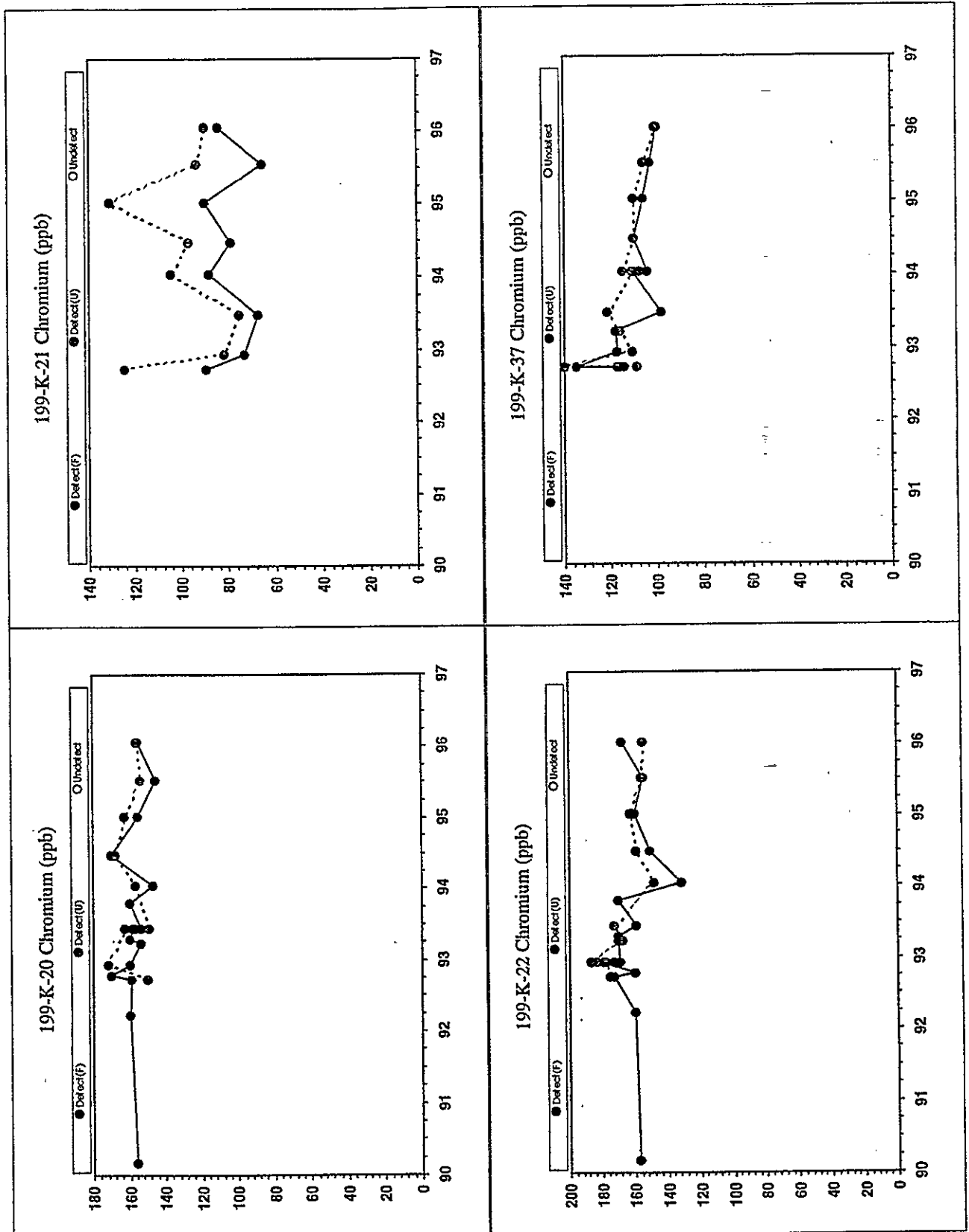


Figure 4-4. Chromium Trends in Selected 100-K Area Near-River Wells

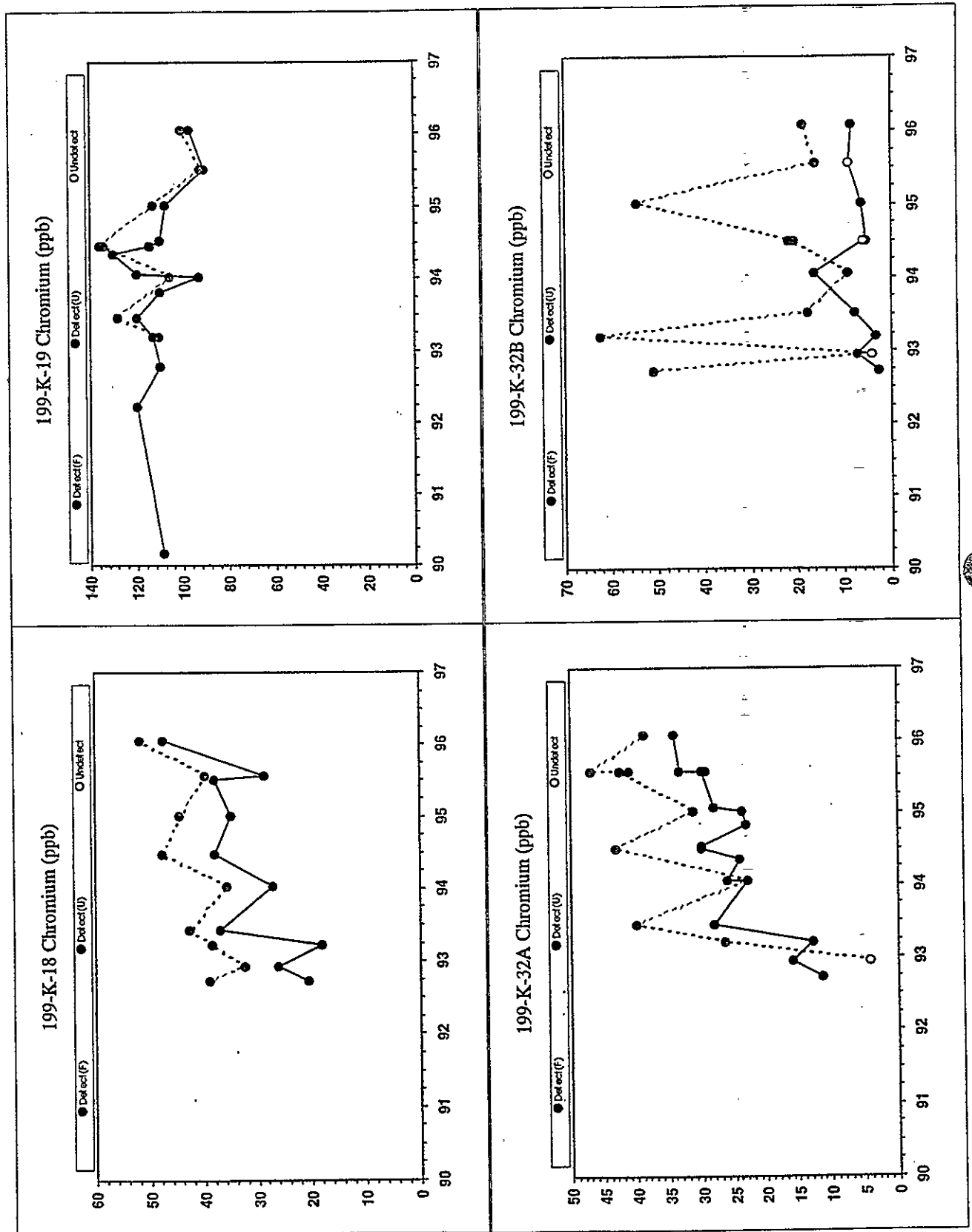
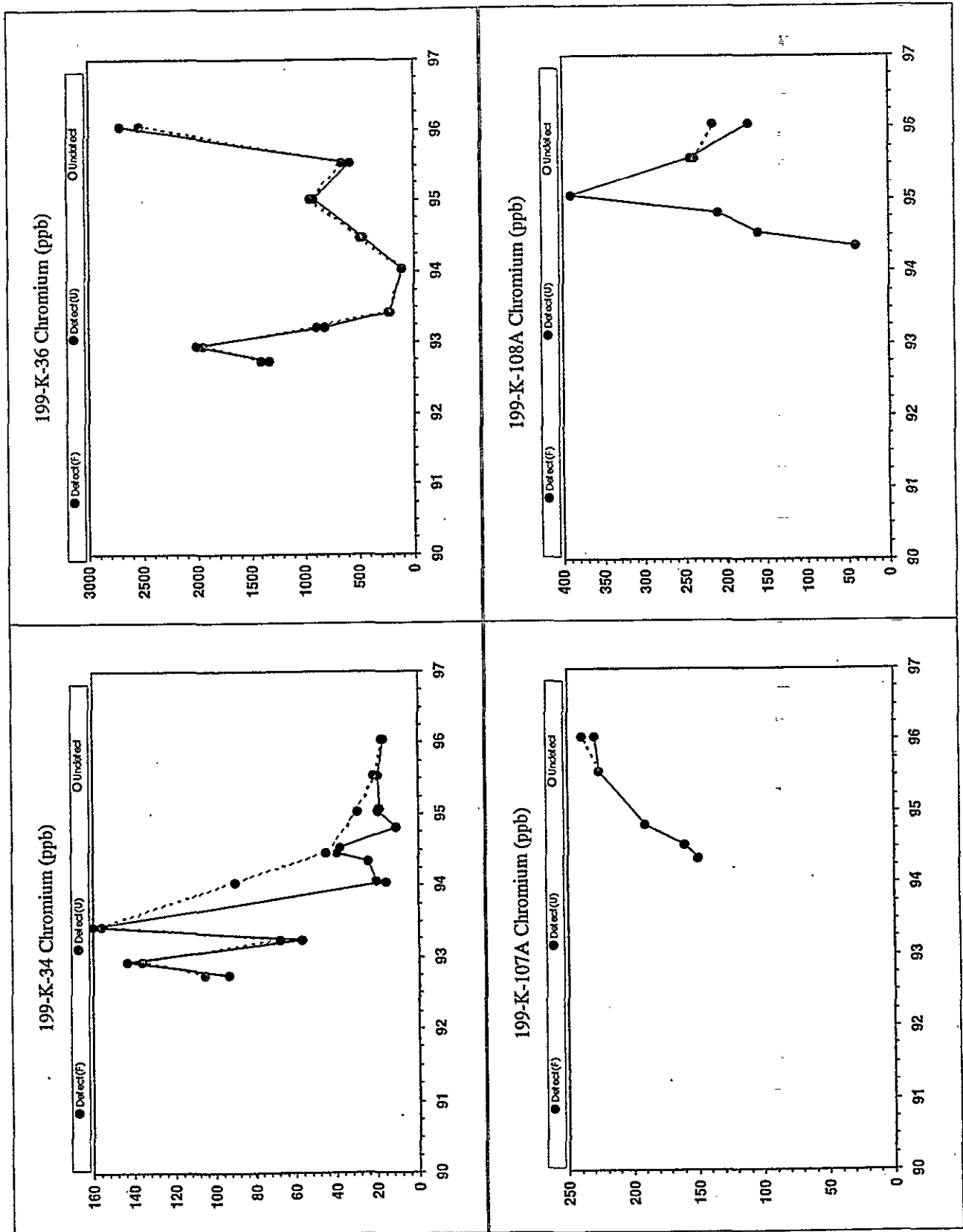


Figure 4-5. Chromium Trends in Selected 100-K Area Inland Hot Spot Wells



**100-KR-4
Tritium Plume &
Water Table Map**

Average concentrations for samples collected between 1/1/95 to 1/25/96 (data evaluation completed)

- Monitoring Well
- e River Bank Seep Location
- Building or Waste Site

50 Tritium Contour -- pCi/L (dashed where inferred)
382 Water Table Contour -- ft (long term average)

Meters
0 150 300

N

Liquid Waste Disposal Tunnel

Retention Basin

105 MW Reactor

105 KFE Reactor

Water Treatment Facility

Outfalls

Monitoring well numbers: 1270, 2235, 1603, 593, 505561, 108355, 129875, 1470, 1012, 250, 2509, 1898, 1403, 3355, 386, 385, 2000, 6083, 18700, 365, 648, 250, 250, 250, 12752, 1139537, 390, 392, 394, 396.

Figure 4-7. Tritium Trends in Selected 100-K Area Wells

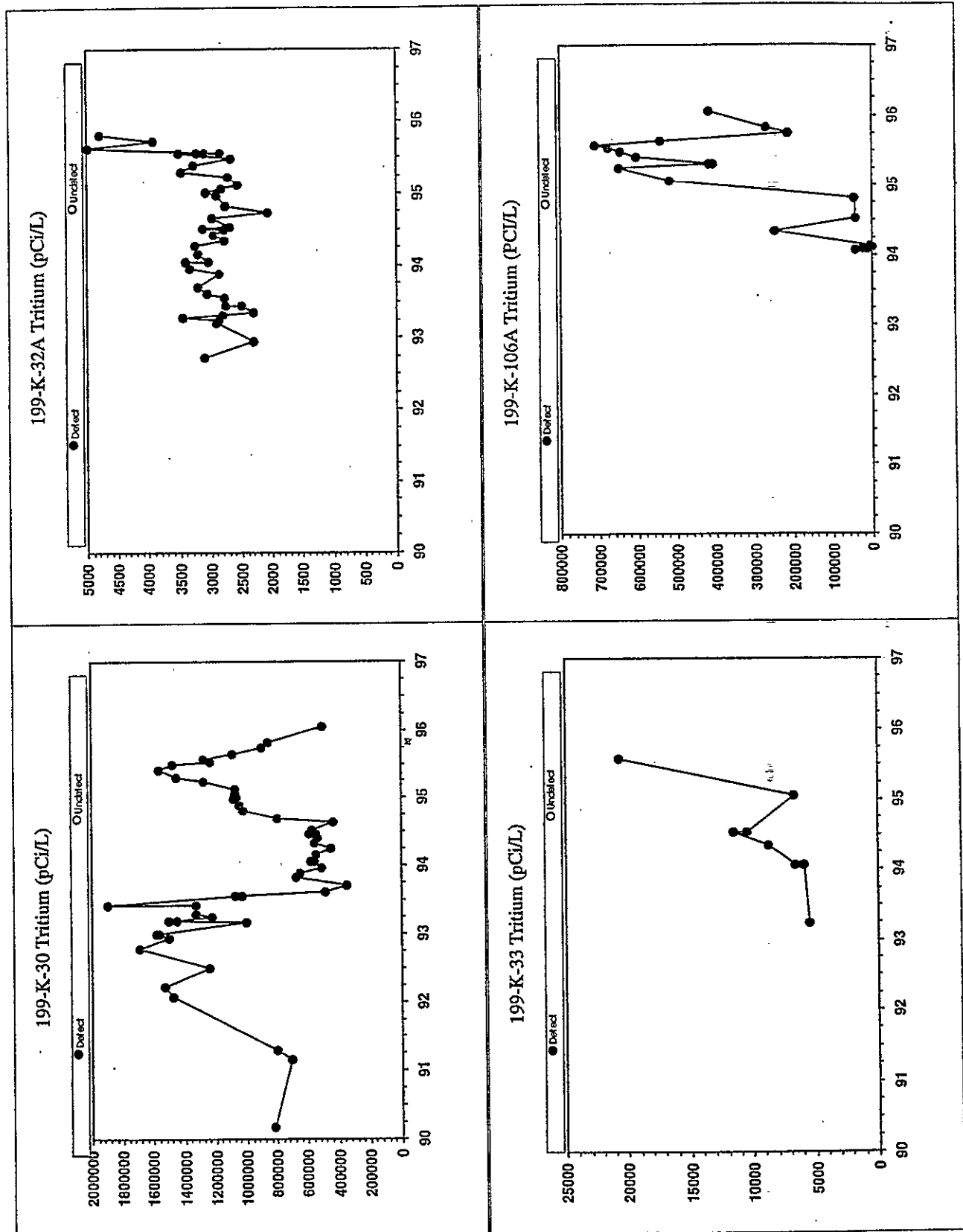
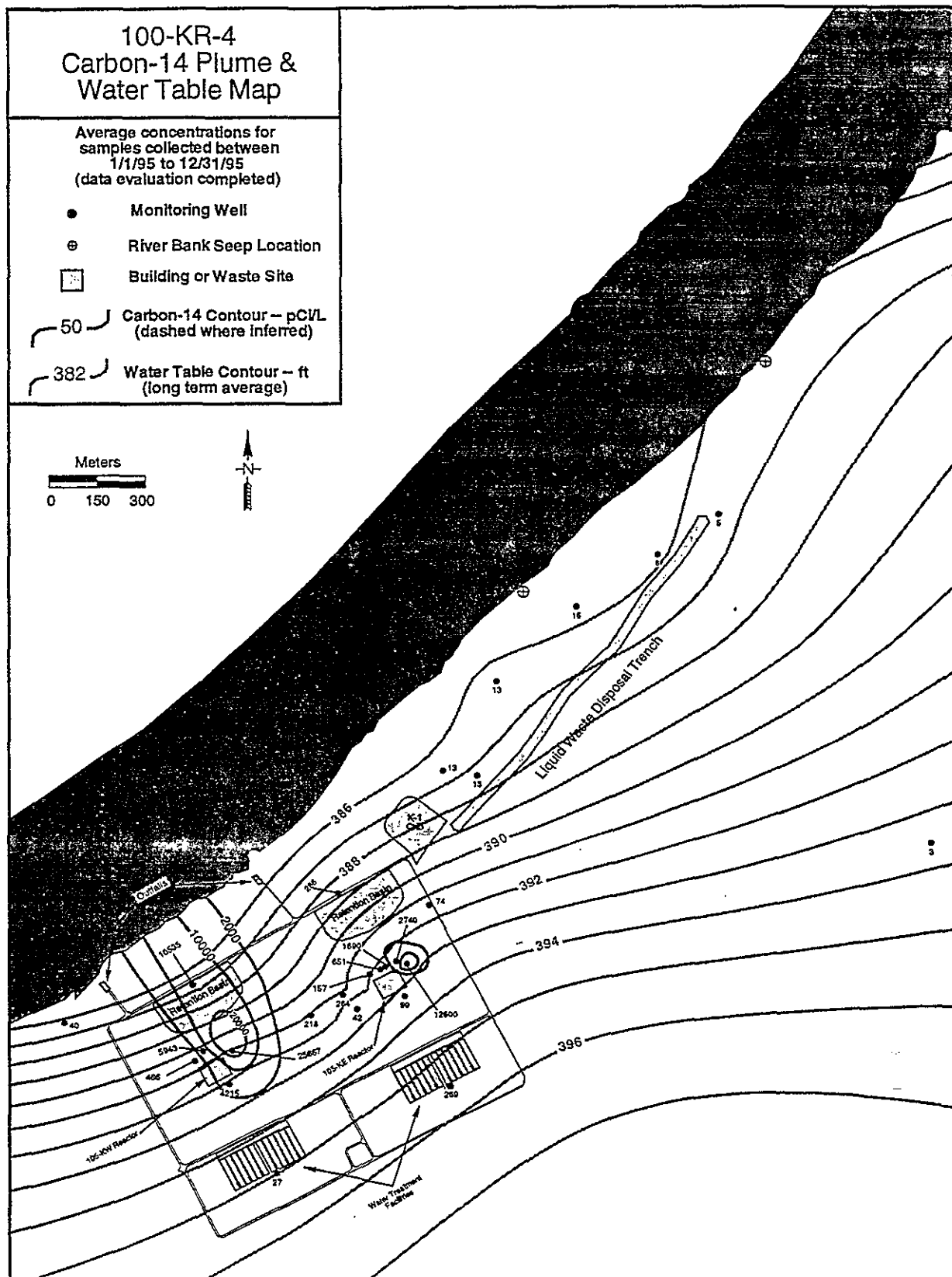


Figure 4-8. Carbon-14 Distribution in the 100-K Area



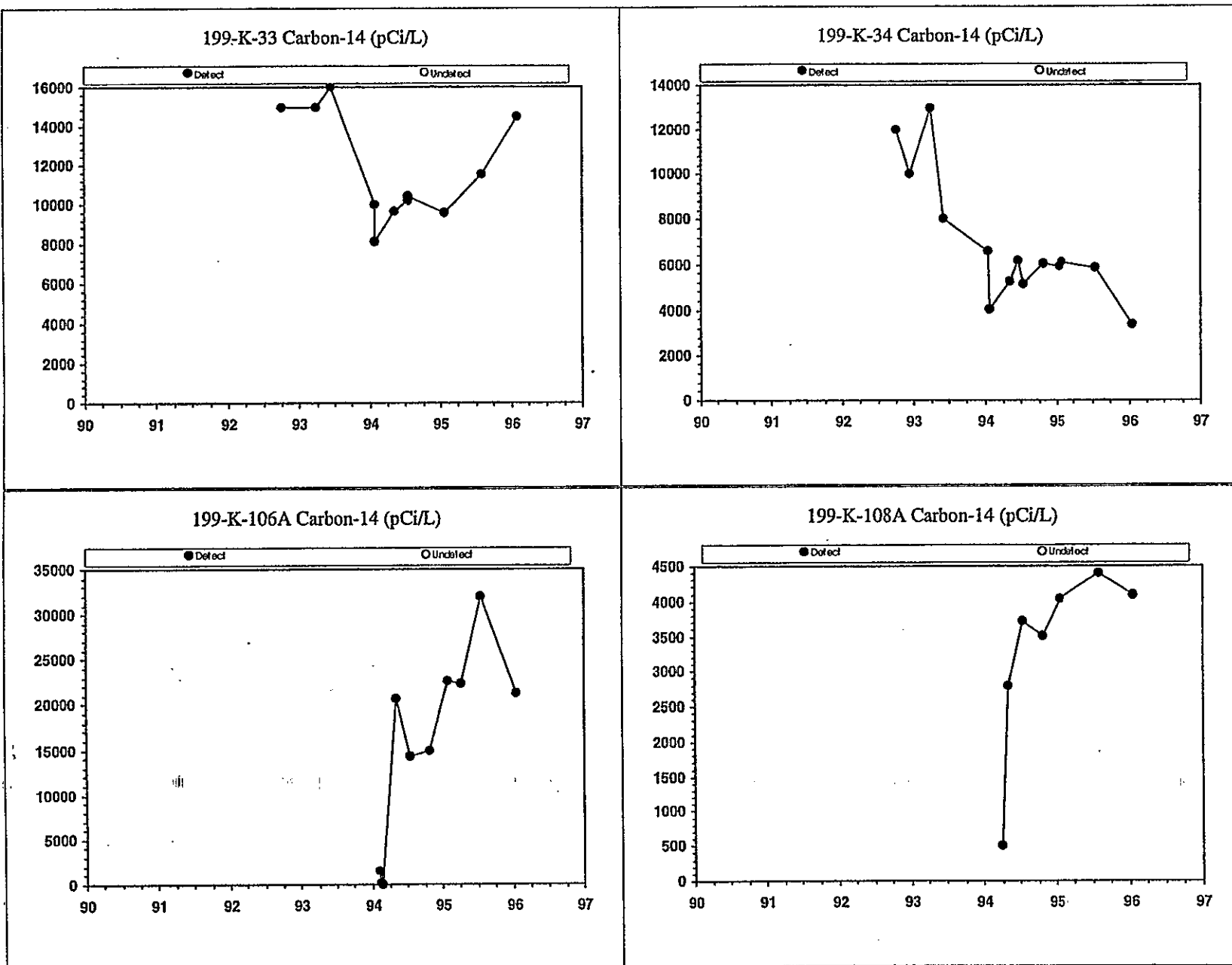


Figure 4-9. Carbon-14 Trends in Selected Wells Near the 105-KW Reactor Building

Figure 4-10. Carbon-14 Trends in Selected Wells Near the 105-KE Reactor Building

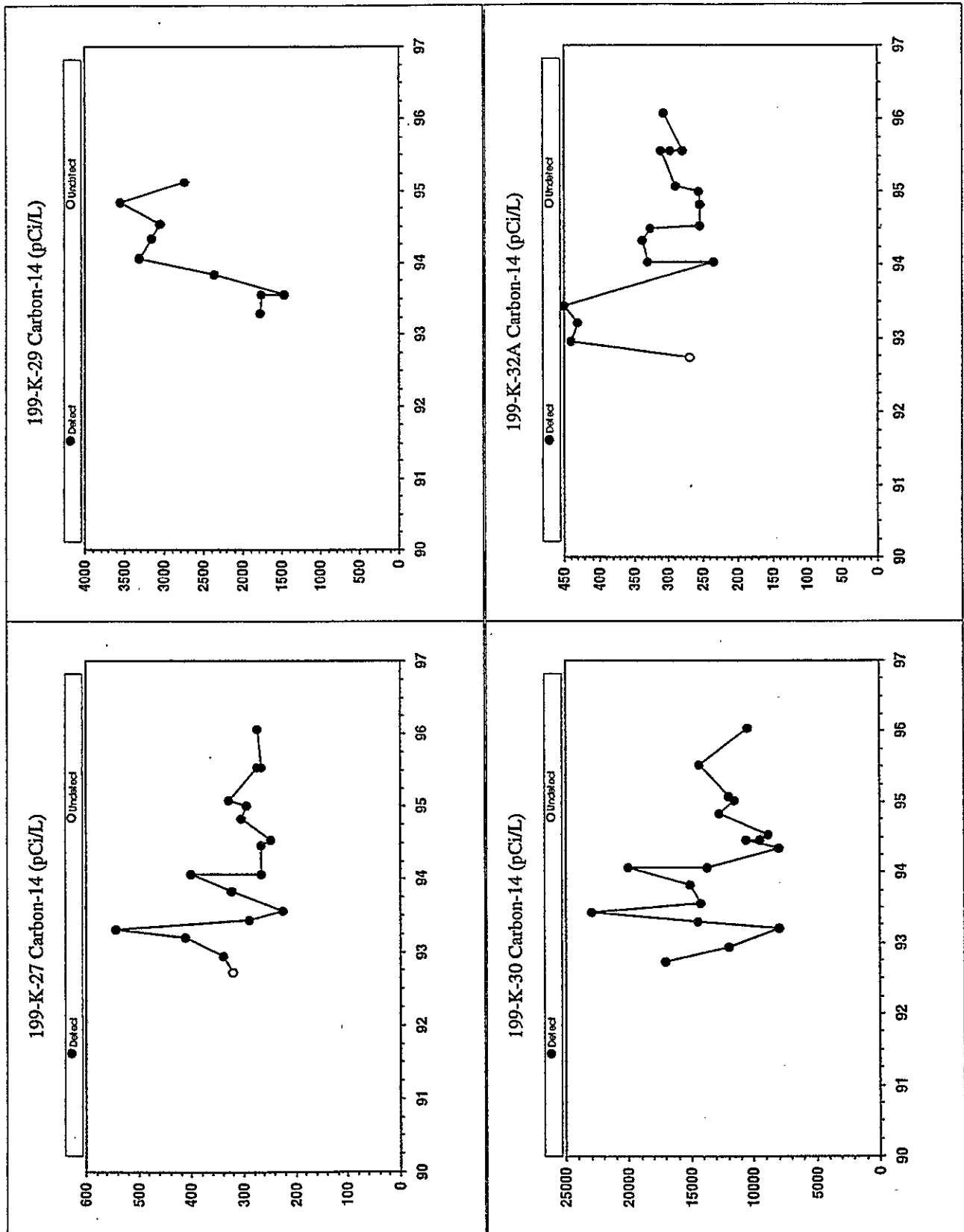


Figure 4-11. Strontium-90 Distribution in the 100-K Area

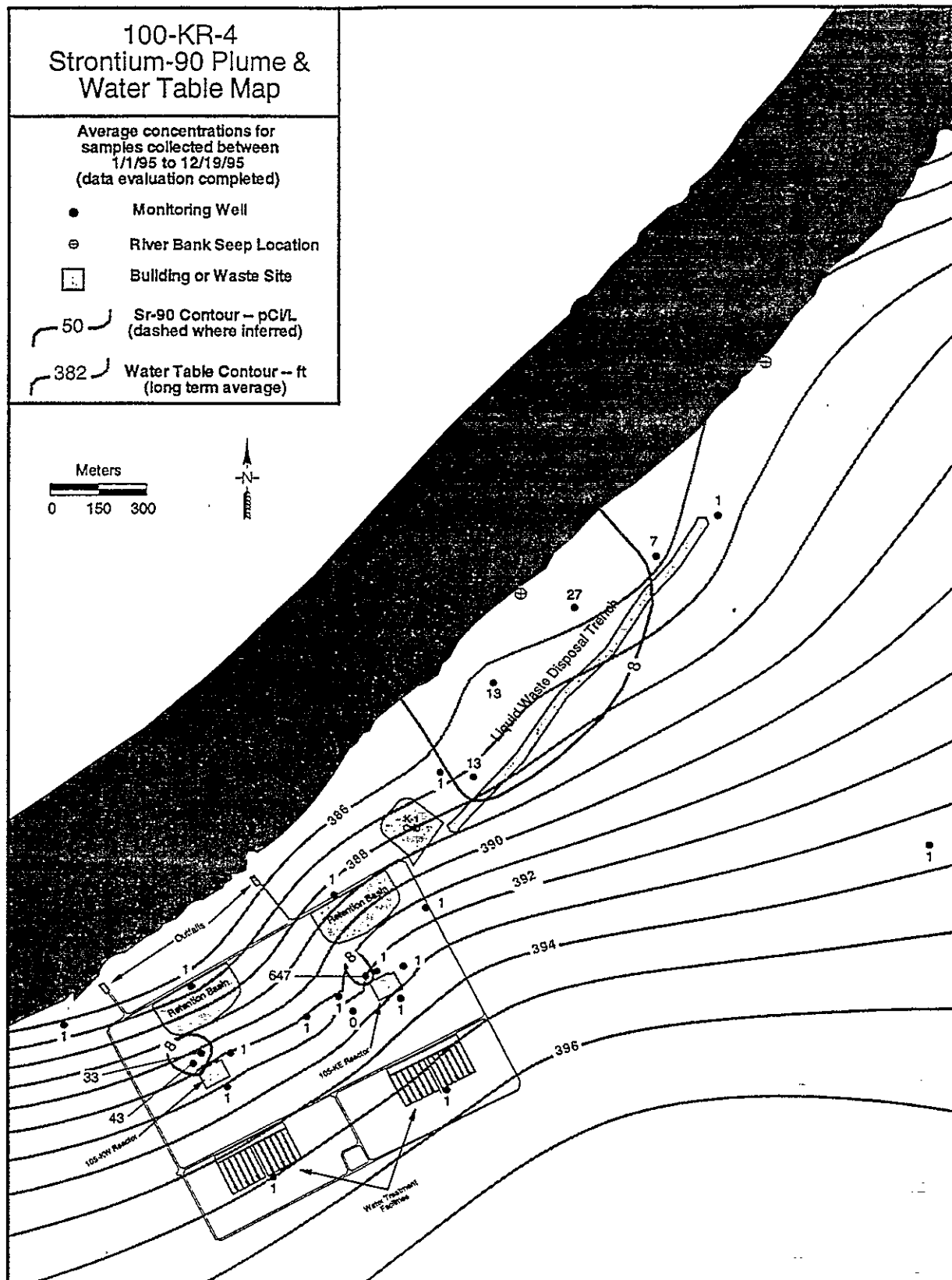


Figure 4-12. Strontium-90 Trends in Selected 100-K IRM Network Wells

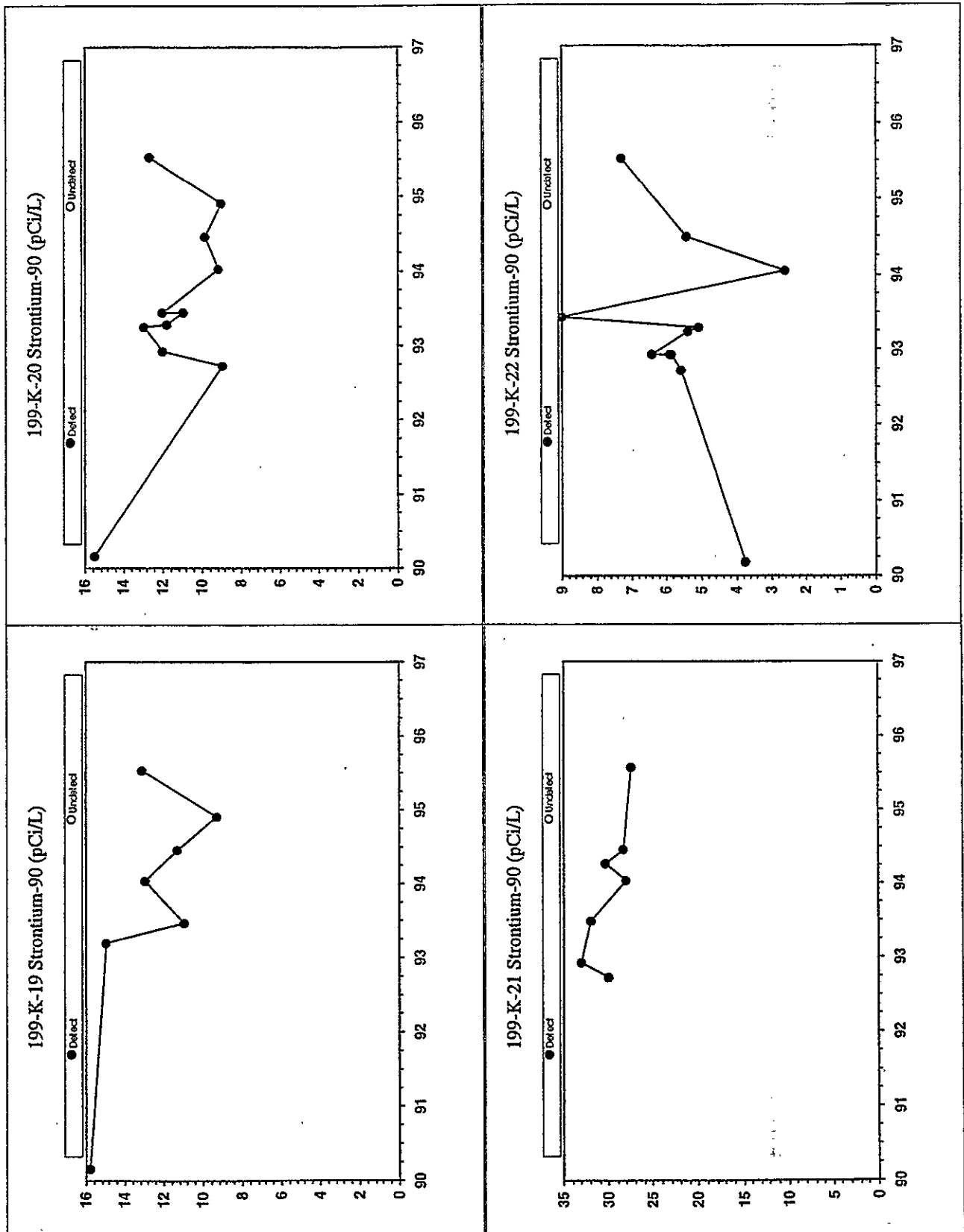


Figure 4-13. Strontium-90 Trends in Selected 100-K Area Inland Hot Spot Wells

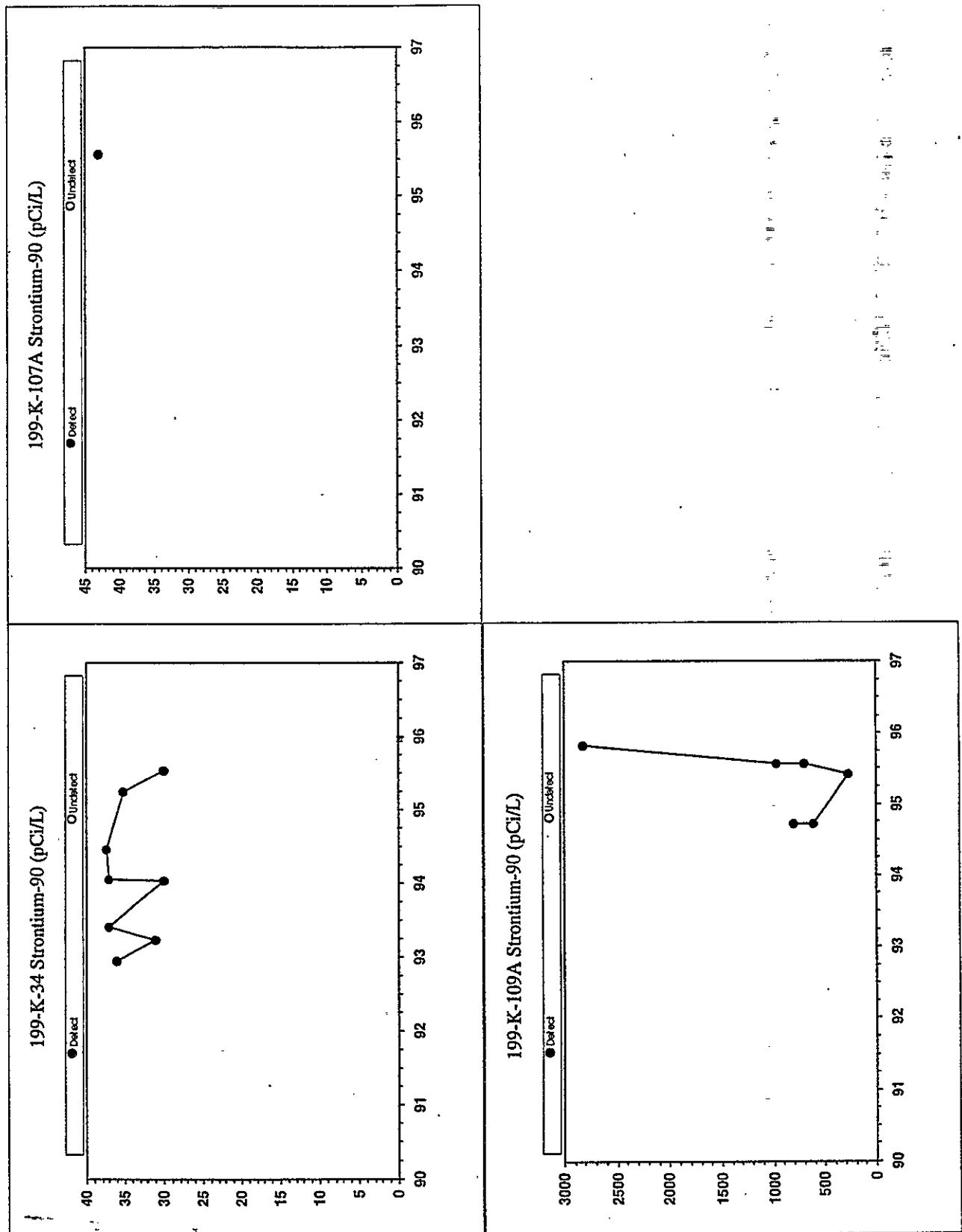


Figure 4-14. Nitrate Distribution in the 100-K Area

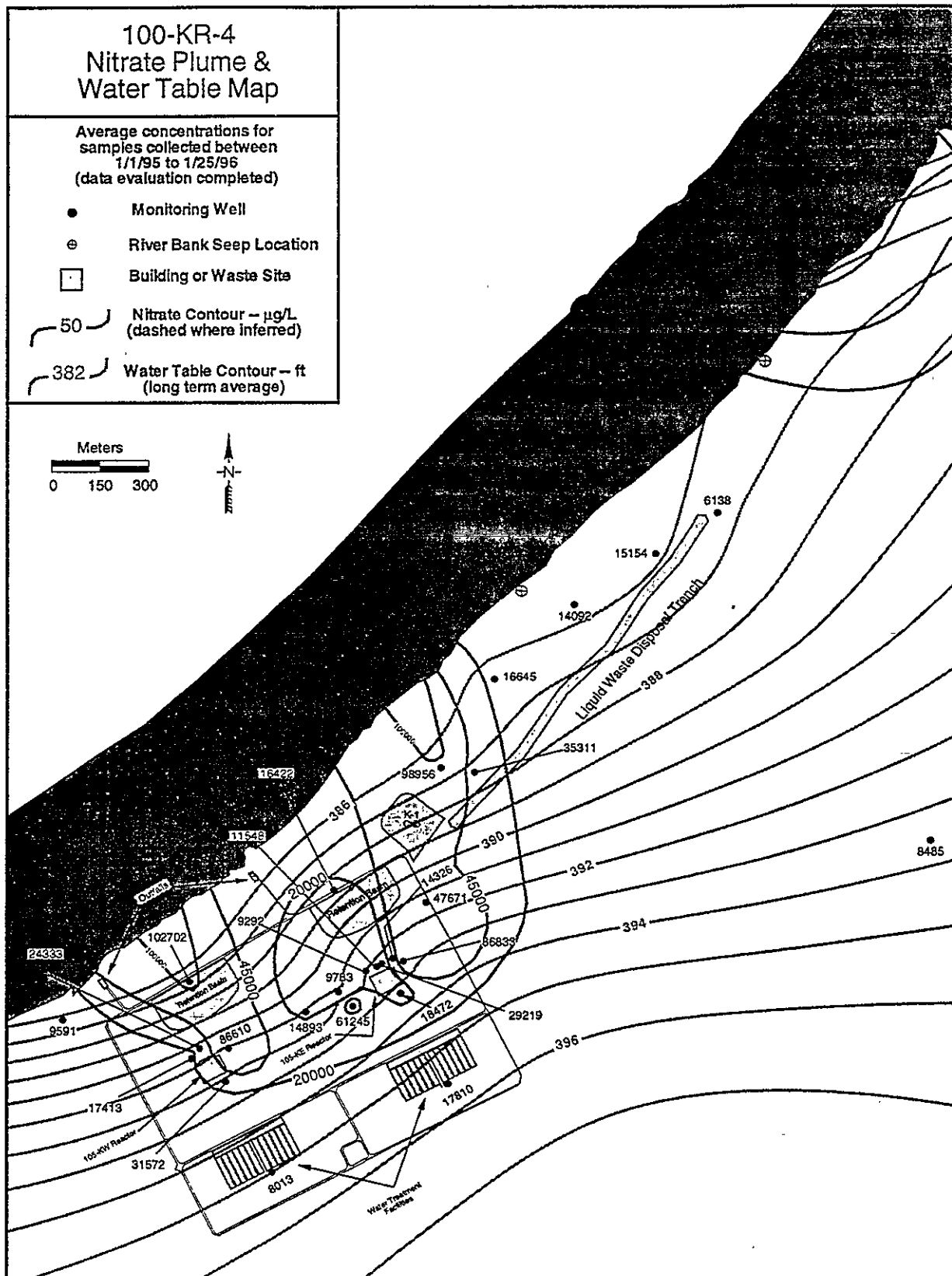


Figure 4-15. Cross Section (A-A') Parallel to 100-K Area Shoreline

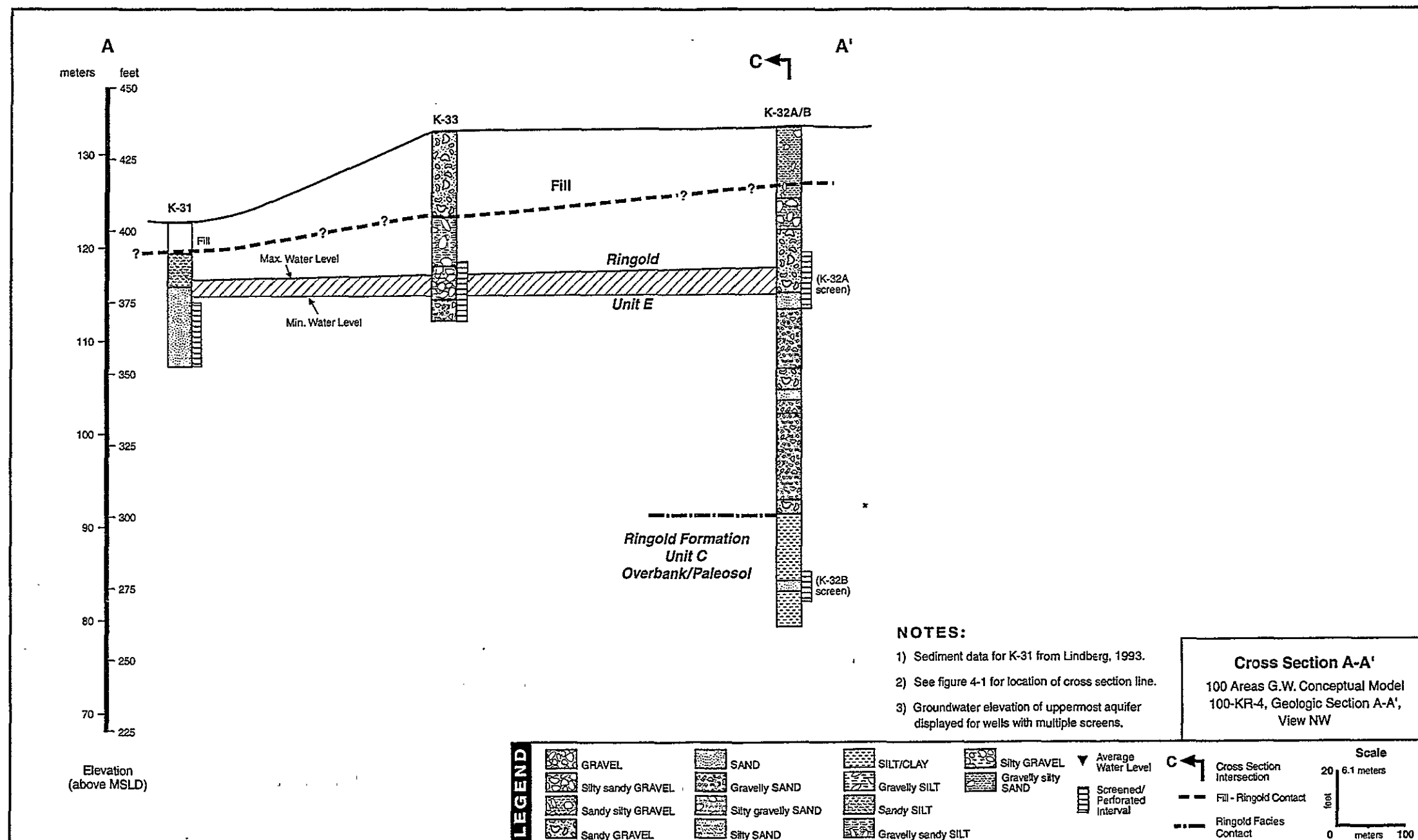


Figure 4-16. Cross Section (B-B') Parallel to 100-K Area Shoreline

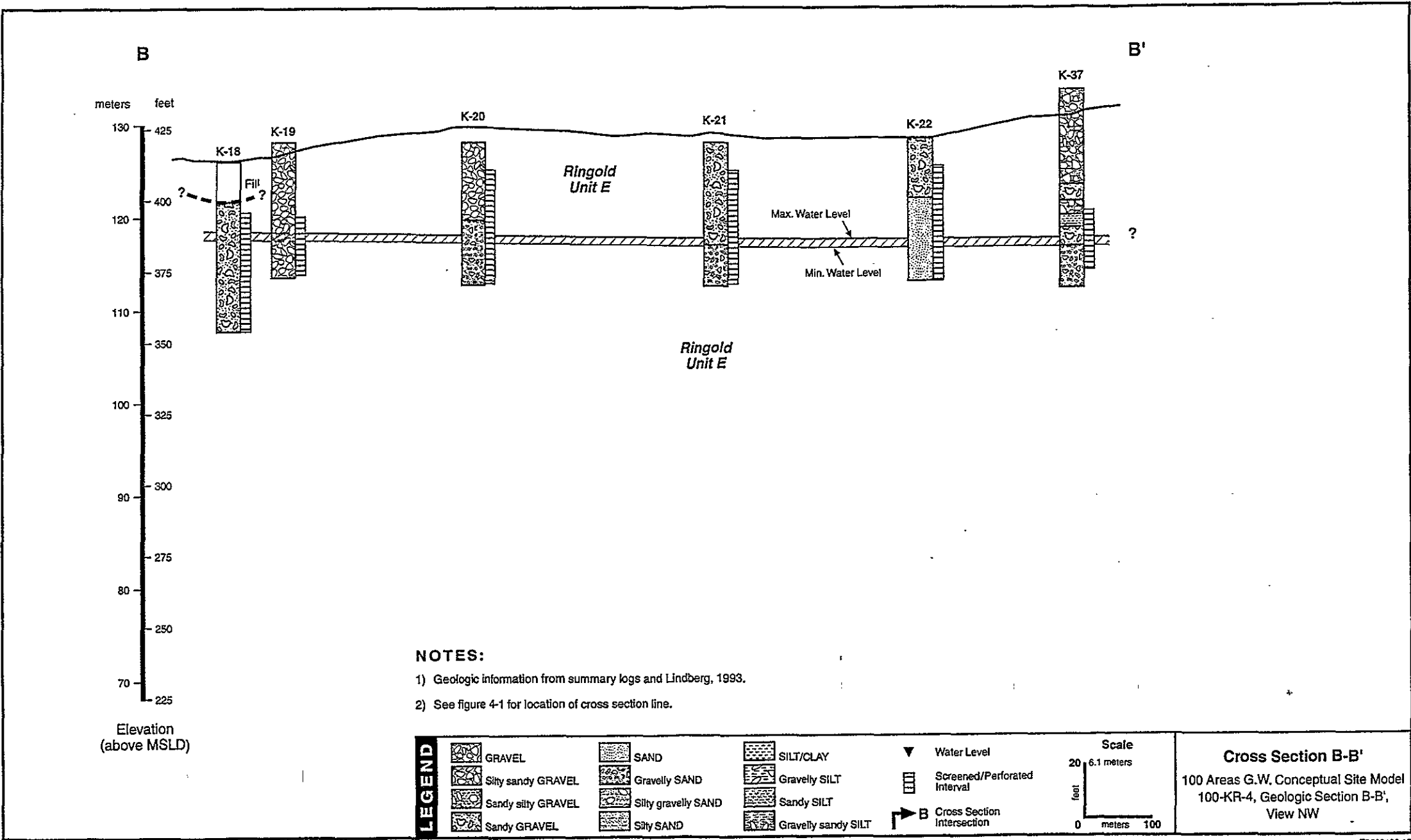


Figure 4-17. Cross Section (C-C') Perpendicular to the 100-K Area Shoreline

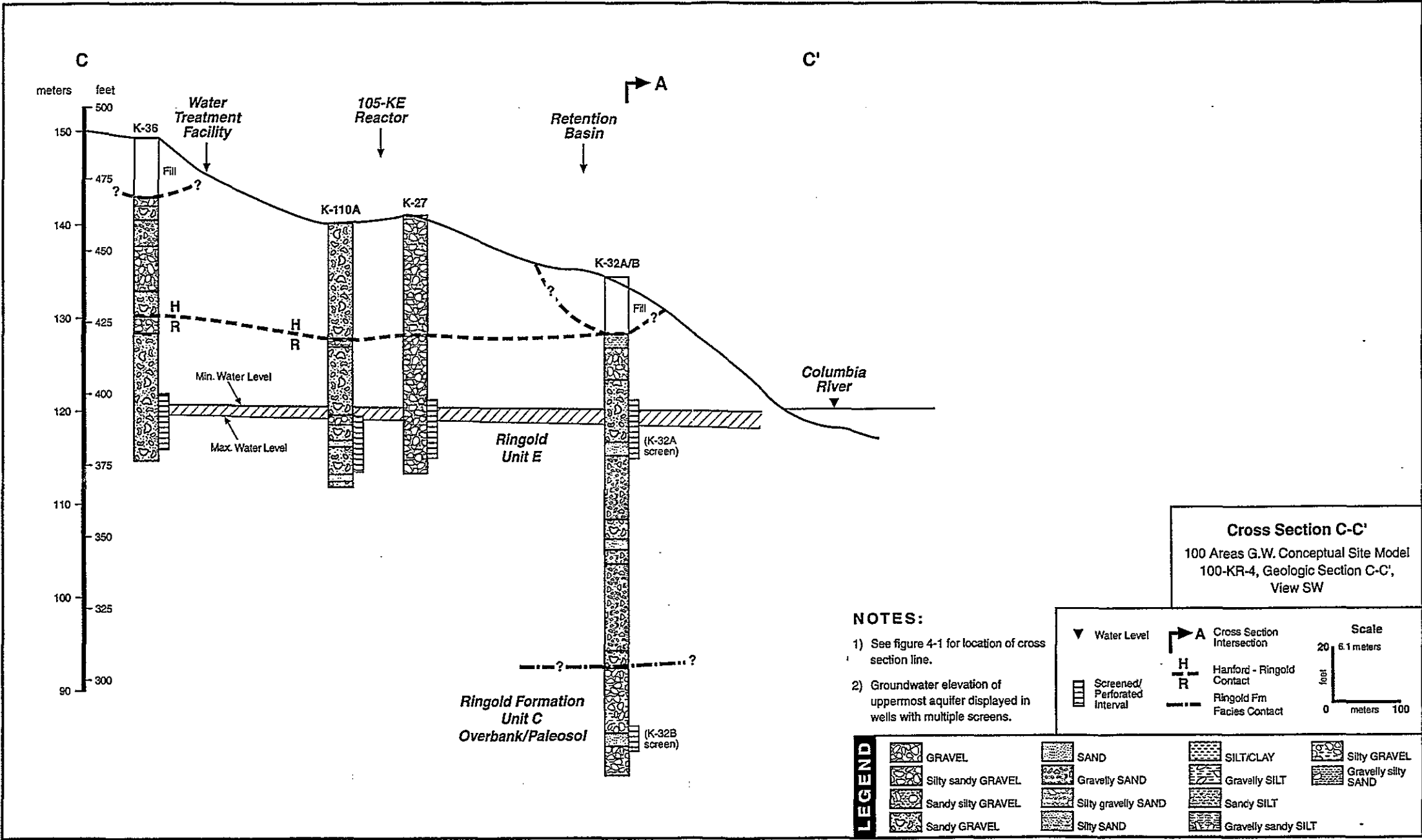
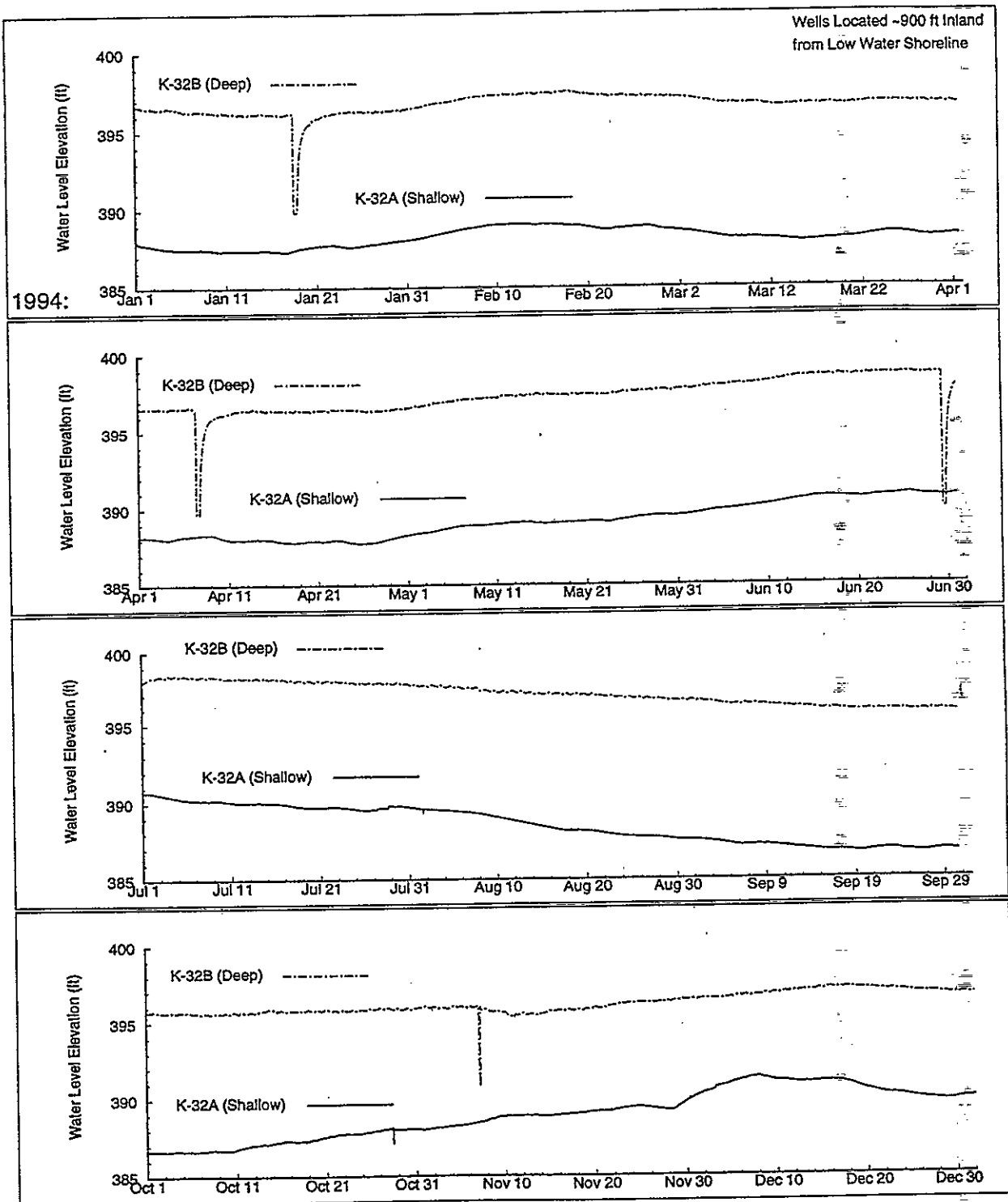


Figure 4-18. Hydrographs For Shallow and Deep Wells in the 100-K Area



100-KR-4 Chemical Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Defects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
1,1,1-Trichloroethane	ppb	N	7	10	0	0.00	0.00	0.00	200	MCL	0	0	
Aluminum	ppb	N	28	92	27	23.80	228.00	55.20	50	SMCL	10	0	
Aluminum	ppb	Y	30	114	20	26.00	40.80	31.53	50	SMCL	0	0	6.86
Arsenic	ppb	N	22	33	22	1.50	14.00	4.90	50	MCL	0	0	
Arsenic	ppb	Y	22	33	22	1.40	12.50	4.60	50	MCL	0	0	8.06
Barium	ppb	N	28	92	84	14.10	72.80	31.99	1000	MCL	0	0	
Barium	ppb	Y	30	114	106	13.90	72.60	32.16	1000	MCL	0	0	91.57
Cadmium	ppb	N	28	92	1	2.30	2.30	2.30	10	MCL	0	0	
Cadmium	ppb	Y	30	114	2	3.50	3.70	3.60	10	MCL	0	0	3.07
Chloride	ppb	N	30	233	233	2500.00	110000.00	19939.66	250000	SMCL	0	0	16863.99
Chromium	ppb	N	28	92	67	3.00	2530.00	122.77	50	MCL	27	0	
Chromium	ppb	Y	30	113	72	3.00	2710.00	114.30	50	MCL	25	9	16.61
Copper	ppb	N	28	92	47	1.90	38.60	10.33	1300	MCL-P	0	0	
Copper	ppb	Y	30	114	51	1.10	57.00	10.30	1300	MCL-P	0	0	0.85
Fluoride	ppb	N	30	237	215	86.00	1100.00	378.00	1400	MCL	0	0	904.00
Iron	ppb	N	28	92	64	18.80	2540.00	279.90	300	SMCL	16	0	
Iron	ppb	Y	30	114	62	8.50	994.00	66.46	300	SMCL	2	2	415.86
Lead	ppb	N	22	33	3	0.91	2.70	2.07	50	MCL	0	0	
Lead	ppb	Y	22	33	3	1.50	4.10	2.47	50	MCL	0	0	3.47
Manganese	ppb	N	28	92	59	1.10	50.70	9.09	50	SMCL	1	0	
Manganese	ppb	Y	30	114	66	0.98	52.70	5.81	50	SMCL	1	1	40.11
Mercury	ppb	N	22	27	0	0.00	0.00	0.00	2	MCL	0	0	
Mercury	ppb	Y	22	27	1	0.16	0.16	0.16	2	MCL	0	0	0.00
Nickel	ppb	N	28	92	15	14.60	110.00	46.49	100	MCL	1	0	
Nickel	ppb	Y	30	114	7	40.00	97.20	73.09	100	MCL	0	0	2.19
Nitrate	ppb	N	30	231	231	2280.00	129705.24	32145.96	45000	MCL	58	6	31725.97
Selenium	ppb	N	22	33	6	1.10	2.40	1.45	10	MCL	0	0	
Selenium	ppb	Y	22	33	6	1.20	94.70	17.58	10	MCL	1	1	6.01
Silver	ppb	N	28	92	2	5.00	15.50	10.25	50	MCL	0	0	
Silver	ppb	Y	30	114	0	0.00	0.00	0.00	50	MCL	0	0	5.68
Sulfate	ppb	N	30	237	235	13100.00	151000.00	34373.19	250000	SMCL	0	0	84676.12
Trichloroethene	ppb	N	7	10	9	0.50	35.00	6.26	5	MCL	2	2	
Uranium	ppb	N	6	8	8	1.34	5.93	4.18	44	UMTR	0	0	9.28
Zinc	ppb	N	28	92	74	6.00	332.00	45.79	5000	SMCL	0	0	21.47
Zinc	ppb	Y	30	114	85	5.40	370.00	30.05	5000	SMCL	0	0	21.47

Table 4-1. Constituents Summary for 100-KR-4 Operable Unit (Page 1 of 2)

100-KR-4 General Properties

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Defects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Dissolved Oxygen	mg/L	N	28	55	55	2.50	503.00	16.85			0	0	14935.41
pH Measurement	pH	N	30	255	255	6.57	10.45	7.80			0	0	8.07
Specific Conductance	umhos/cm	N	30	297	297	240.00	1037.00	453.79			0	0	428.00
Temperature	Deg C	N	30	253	253	9.80	25.10	16.35			0	0	

100-KR-4 Radiological Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Defects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Carbon-14	pCi/L	N	30	103	73	3.96	32000.00	3146.03	2000	MCL	19	6	152.79
Gross Alpha	pCi/L	N	30	166	130	1.02	9.10	3.24	15	MCL	0	0	2.47
Gross Beta	pCi/L	N	30	177	177	3.21	9379.30	310.90	50	MCL	38	6	7.44
Strontium-89/90	pCi/L	N	28	35	11	1.15	1090.00	110.54			0	0	0.02
Strontium-90	pCi/L	N	28	47	26	0.00	6089.00	509.11	8	MCL	12	6	0.02
Technetium-99	pCi/L	N	6	12	12	0.34	115.00	47.46	900	MCL	0	0	1.78
Tritium	pCi/L	N	30	232	195	53.30	1560000.00	137898.43	20000	MCL	66	6	162.00
Uranium-233/234	pCi/L	N	5	6	6	0.89	2.18	1.49			0	0	1.48
Uranium-234	pCi/L	N	27	84	76	0.42	4.52	1.64			0	0	
Uranium-235	pCi/L	N	27	94	9	0.07	0.61	0.27			0	0	0.08
Uranium-238	pCi/L	N	27	91	79	0.27	4.10	1.35			0	0	1.28

Data Source: Hanford Environmental Information System. Abbreviations: MCL = EPA maximum contaminant level (primary); MCL-P = EPA maximum contaminant level (proposed); SMCL = EPA maximum contaminant level (secondary); EPA 440/5-86-001-USEPA Freshwater Chronic Water Quality Criteria; and UMTR = Uranium Mining Tailings Reclamation. "Background Values" are provisional 90th percentile values taken from Hanford Site Background: Part 3, Groundwater (DOE/RL-96-91, Decisional Draft)

Table 4-1. Constituents Summary for 100-KR-4 Operable Unit (Page 2 of 2)

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Table 4-2. Constituents in 100-K Area Wells that Exceed Standards (Page 1 of 2)

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Carbon-14 (2,000 pCi/L)	199-K-106A	32,000	1,580	Gas condensate disposal to the 105-KE and 105-KW french drains, located on the east side of each reactor building.
	199-K-108A	4,400	1,820	
	199-K-29	2,740	1,850	
	199-K-30	14,300	1,910	
	199-K-33	14,500	800	
	199-K-34	6,090	1,390	
Chromium (50 µg/L)	199-K-107A	229	1,350	Main plume comes from the 100-K Mile Long Trench, a liquid waste disposal facility that received reactor coolant effluent and decontamination solutions.
	199-K-108	390	1,820	
	199-K-19	108	1,100	
	199-K-20	155	560	
	199-K-21	90	700	Other miscellaneous chromium sources located near the reactor buildings, and sodium dichromate storage tanks at the south end of the 183-K treatment plants.
	199-K-22	167	1,060	
	199-K-23	63	1,890	
	199-K-36	2,710	3,100	
Gross Beta (50 pCi/L)	199-K-107A	98	1,350	(see strontium-90)
	199-K-109A	9,379	1,770	
	199-K-21	61	700	
	199-K-30	97	1,910	
	199-K-34	92	1,390	
	699-70-68	60		
Iron (300 µg/L)	199-K-13	994	1,680	Common natural constituent in groundwater; possible association with carbon-steel well casing.
	199-K-34	621	1,390	
Manganese (50 µg/L)	199-K-13	53	1,680	(same as iron)
Nitrate (45,000 µg/L)	199-K-106A	94,291	1,580	Widely distributed in reactor areas. Common source is disposal of nitric acid decontamination solutions.
	199-K-111A	52,236	2,160	
	199-K-18	105,358	840	
	199-K-23	67,287	1,890	
	199-K-30	129,705	1,910	
	199-K-33	109,785	800	
Selenium (10 µg/L)	199-K-27	95	1,800	
Strontium-90 (8 pCi/L)	199-K-107A	43	1,350	Common in reactor coolant effluent, especially during fuel element rupture episode. Also common in effluent from fuel storage basins, which was disposed to a tile field located at the northwest corner of each reactor building.
	199-K-109A	6,089	1,770	
	199-K-19	13	1,100	
	199-K-20	13	560	
	199-K-21	27	700	
	199-K-34	35	1,390	

Table 4-2. Constituents in 100-K Area Wells that Exceed Standards (Page 2 of 2)

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Trichloroethene (5 $\mu\text{g/L}$)	199-K-106A	35	1,580	Isolated occurrence--unexplained.
	199-K-33	14	800	
Tritium (20,000 pCi/L)	199-K-106A	711,000	1,580	Main component of gas condensate disposed to French drains near reactor buildings (see carbon-14 above)
	199-K-109A	180,000	1,770	
	199-K-18	22,600	840	
	199-K-27	234,000	1,800	
	199-K-30	1,560,000	1,910	
	199-K-33	45,000	800	

Table 4-3. 100-KR-1 Source Operable Unit High-Priority Waste Sites

Waste Site Number/Name	Former Waste Site Use	Physical Waste Site Description	⁽¹⁾ Contaminants of Potential Concern
116-K-1 Crib	Received 40 million liters of radioactive reactor cooling effluent wastes contaminated by fuel cladding ruptures.	Crib area is 61 m x 61 m. Crib surrounded by earthen embankment extending 6.1 m above crib bottom. Outer edge of embankment encompasses area 122 m x 122 m.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239/240
116-K-2 Process Effluent Trench	Received 300 billion liters of contaminated effluent that included radioactive reactor cooling effluent and contaminated water from floor drains in 105-KE and 105-KW Reactors. Also buried in the trench is a construction tractor and all "hydride" tanks from the 100-K Area.	Open trench 1249.7 m long, 13.7 m wide, and 7.6 m deep. Trench was excavated 5.3 m below grade and surrounded by a berm 2.3 m high. About 6.6 m of fill placed in trench in 1971, except at inlet end of trench. First 290 m of trench, the inlet end, now contains about 6.8 m of fill.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239/240, Sr-90, Th-228, chromium, mercury
116-KW-3 Retention Basins	Held cooling water effluent from 105-KW Reactor for cooling/decay before release to the Columbia River.	Three open-topped welded carbon steel tanks 76.2 m dia. x 8.8 m high. Approximately 3/4 of the tank walls have been removed.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239/240, Th-228, Th-232, U-233/234, U-238
116-KE-4 Retention Basins	Held cooling water effluent from 105-KE Reactor for cooling/decay before release to the Columbia River.	Three open-topped welded carbon steel tanks 76.2 m dia. x 7.62 m high. Approximately 3/4 of the tank walls have been removed.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239/240, Th-228, Th-232
100-KR-1 Buried Process Effluent Pipelines	Transported reactor cooling water to retention basins, 116-K-3 outfall structure, 116-K-1 crib, and 116-K-2 trench. Contains contaminated sludge and scale.	Lines are 183 cm, 168 cm, 152 cm, 107 cm, 91 cm, and 30 cm in diameter; buried 1.9 m to 5.2 m below grade.	Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-239/240

⁽¹⁾ The contaminants of potential concern were identified from the qualitative risk assessment.

Cs-137 = ¹³⁷Cesium
 Co-60 = ⁶⁰Cobalt
 Eu-152 = ¹⁵²Europium
 Eu-154 = ¹⁵⁴Europium
 Eu-155 = ¹⁵⁵Europium

Pu-239/240 = ^{239/240}Plutonium
 Sr-90 = ⁹⁰Strontium
 Th-228 = ²²⁸Thorium
 Th-232 = ²³²Thorium
 U-233/234 = ^{233/234}Uranium
 U-238 = ²³⁸Uranium

Table 4-4. 100-KR-2 Source Operable Unit High-Priority Waste Sites (Page 1 of 2)

Site Number/ Name (Alias)	Previous Use	Physical Description	Contaminants of Potential ^(a) Concern
116-KE-1 Condensate Crib	Received condensate effluent from the 115-KE reactor gas purification system.	Constructed of 20.3 cm (8 in.) corrugated, perforated, galvanized steel pipe forming a small drain field located in a cobble-filled pit 7.9 m (26 ft) deep. The bottom is 1.8 m (6 ft) in diameter, the top is 17.3 m (57 ft) in diameter. The perforated pipe is located 5.3 m (17.5 ft) belowgrade.	¹⁴ C, ³ H
116-KE-2 Crib	Received liquid wastes from test loops, cleanup columns (ion exchange columns), and contaminated cooling water.	Constructed of wooden timbers forming a cobble-filled 4.9 x 4.9 m (16 x 16 ft) crib. The crib structure rests in a (32 ft) deep pit about 1 m (3 ft) above the excavated bottom. The bottom 3 m (10 ft) of the crib is filled with crushed rock. The crib is penetrated by a perforated well that extends 3.6 m (12 ft) below the crib bottom.	⁶⁰ Co, ^{239/240} Pu, ⁹⁰ Sr
116-KE-3 French Drain	Received liquid effluent from the 105-KE Fuels Storage Basin.	Constructed of a 20.3 cm (8 in.) steel well casing extending to 3 m (10 ft) below groundwater with an overflow drain field located about 8.8 m (29 ft) belowgrade. It is about 3 m (10 ft) in diameter at the bottom and 6.1 m (20 ft) in diameter at the top of the structure.	^(b) ¹³⁷ Cs, ⁶⁰ Co, ¹⁵² Eu, ¹⁵⁴ Eu, ^{239/240} Pu
116-KW-1 Condensate Crib	Received condensate effluent from the 115-KW reactor gas purification system.	Constructed of a 20.3 cm (8 in.) corrugated, perforated, galvanized steel pipe, forming a small drain field located in a cobble-filled pit 7.9 m (26 ft) deep. The bottom is 1.8 m (6 ft) in diameter, the top about 17.3 m (57 ft) in diameter. The perforated pipe is located 5.3 m (17.5 ft) belowgrade.	¹⁴ C, ³ H
116-KW-2 French Drain	Received liquid effluent from the 105-KW Fuels Storage Basin.	Constructed of a 20.3 cm (8 in.) steel well casing extending to 3 m (10 ft) below groundwater with an overflow drain field located about 8.8 m (29 ft) belowgrade. It is about 3 m (10 ft) in diameter at the bottom and 6.1 m (20 ft) in diameter at the top of the structure.	^(b) ¹³⁷ Cs, ⁶⁰ Co, ¹⁵² Eu, ¹⁵⁴ Eu, ^{239/240} Pu
118-K-2 Sludge Trench	May have received radioactive sludge removed from the 100-K Area Retention Basins.	Exact location unknown. Construction would have been a shallow (up to 4.5 m [15 ft] deep) trench or pit backfilled immediately after use.	^(b) ¹⁴ C, ¹³⁷ Cs, ⁶⁰ Co, ¹⁵² Eu, ¹⁵⁴ Eu, ²³⁸ Pu, ^{239/240} Pu, ⁹⁰ Sr, ²²⁸ Th, arsenic, cadmium, chromium, and lead
119-KW French Drain	Received liquid wastes from a floor drain, swamp cooler, and heat exchanger in a detection device for radiological contamination in reactor exhaust air.	Constructed of a concrete pipe 0.3 m (1 ft) in diameter placed vertically in the ground. It extends less than 3 m (10 ft) in the ground and is probably gravel filled. It is fed by a single 5.1 cm (2 in.) pipe.	^(b) ¹³⁷ Cs, ⁶⁰ Co, ¹⁵² Eu, ¹⁵⁴ Eu, ^{239/240} Pu

Table 4-4. 100-KR-2 Source Operable Unit High-Priority Waste Sites (Page 2 of 2)

Site Number/ Name (Alias)	Previous Use	Physical Description	Contaminants of Potential ^(a) Concern
118-K-1 Burial Ground	Used to dispose of solid wastes generated in the 100 Area (100-K and 100-N primarily). It also contained an incinerator facility to dispose of combustible low-level radioactive wastes.	The 366 x 183 m (1,200 x 600 ft) burial ground contains many trenches that extend to 6.1 m (20 ft) belowgrade. The site contains six silos that are 3 m (10 ft) in diameter and 7.6 (25 ft) deep. The incinerator is located in the southeast corner of the burial ground. The site contains an estimated 10,000 m ³ (353,150 ft ³) of solid wastes.	^(b) ¹⁴ C, ¹³⁷ Cs, ⁶⁰ Co, ¹⁵² Eu, ¹⁵⁴ Eu, ³ H, ⁶³ Ni, ⁹⁰ Sr, cadmium, lead, mercury, 5% of volume assumed to be contaminated by organics
120-KE-2 French Drain	Received sulfuric acid sludge, containing mercury, and excess sulfuric acid product from filling and maintenance operations.	Constructed of a 1 m (3 ft) in diameter, 1.8 m (6 ft) long, vitrified clay pipe placed vertically in a gravel-filled excavation about 1.8 m (11 ft) deep.	Mercury
120-KW-2 French Drain	Received sulfuric acid sludge, containing mercury, and excess sulfuric acid product from filling and maintenance operations.	Constructed of a 1 m (3 ft) in diameter, 1.8 m (6 ft) long, vitrified clay pipe placed vertically in a gravel-filled excavation about 3.3 m (11 ft) deep.	Mercury

^aThe contaminants of potential concern were identified from the limited field investigation report and qualitative risk assessment.

^bList of contaminants obtained from Waste Site Group Characteristics in *100 Area Source Operable Unit Focused Feasibility Study*.

¹⁴C = Carbon-14
¹³⁷Cs = Cesium-137
⁶⁰Co = Cobalt-60
¹⁵²Eu = Europium-152
¹⁵⁴Eu = Europium-154

³H = Tritium
⁶³Ni = Nickel-63
²³⁸Pu = Plutonium-238
^{239/240}Pu = Plutonium-239/240
⁹⁰Sr = Strontium-90
²²⁸Th = Thorium-228

Table 4-5. Known Facility Sources for Chromium in the 100-K Area

Waste Site Number	Facility Name	Operating Period	Liquid Effluent Summary
116-K-1	100-K Crib	1955	40,000,000 liters of contaminated coolant created during fuel element ruptures; 40 kg sodium dichromate
116-K-2	100-K Mile Long Trench	1955-71	Reactor coolant via 107-K retention basins; KE and KW fuel storage basins overflow; 300 billion liters of KE and KW reactor floor drains; process effluent; other effluents; source for mound on water table under southwest end; 300,000 kg sodium dichromate
116-K-3	1904-K Outfall	1955-present	Reactor coolant and process sewer effluent; possible leakage and release to shoreline via concrete spillway; (NPDES permit for cooling water and water treatment wastes)
116-KE-4	107-KE Retention Basins	1955-71	Temporary storage of coolant, prior to discharge into river; significant leakage to surrounding area and to 100-K mile-long trench via piping;
(Unlisted)	107-KE Retention Basins Leach Trench	1955-65; uncertain	Trench to direct coolant leakage from basins toward river; possible 10,000 to 20,000 gpm leak rates
116-KW-3	107-KW Retention Basins	1954-70	Temporary storage of coolant, prior to discharge into river; significant leakage associated with structure and piping; possible "leach trenches" that diverted leakage to river shoreline
116-KE-2	1706-KER Waste Crib	1955-71	3,000,000 liters of liquid wastes from test loops and cleanup columns; contaminated coolant from fuel element ruptures on emergency basis
120-KE-6	183-KE Sodium Dichromate Tank	1955-71	42,000 gal tank for storage of sodium dichromate stock solution; possible leakage during routine transfer operations; residual dichromate in soil
120-KW-5	183-KW Sodium Dichromate Storage Tank	1955-71	42,000 gal tank for storage of sodium dichromate stock solution; possible leakage during routine transfer operations; residual dichromate in soil

Source: 100-K Technical Baseline Report, WHC-SD-TI-239, Rev. 0, April 1994, (Carpenter and Coté, 1994)

Table 4-6. Hydrogeologic Units Monitored by 100-K Area Wells

Well	Screened Interval Elevation; meters/(ft)	Hydrogeologic Unit	Average Ground- water Elevation meters/(ft)
K-32A	120.8 - 114.7 m (396.3 - 376.3 ft)	Ringold Formation Unit E	118.5 m/ (388.6 ft)
K-32B	86.8-83.8 m (284.7 - 274.7 ft)	Ringold Formation overbank/paleosol	121.0 m/(396.8 ft)

Notes:

1. Groundwater elevations averaged from quarterly steel tape measurements conducted from 1-1-94 to 8-30-95.
2. Screened intervals from unpublished Westinghouse Hanford Company geologic well summaries.
3. Survey elevations from ICF Kaiser Hanford, 1992.



Table 4-7. Water Level and Specific Conductance in 100-K Area Wells (Page 1 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μS/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
Wells representative of conditions at or near the water table:											
199-K-31	350	386.25	6.7	383.0	389.7	12	297	51	265	316	4
199-K-20	560	386.35	4.3	384.5	388.8	14	321	27	307	334	5
199-K-21	700	385.57	3.7	384.2	388.0	13	334	117	299	416	5
199-K-33	800	386.66	5.9	384.1	390.0	15	596	170	489	659	9
199-K-18	840	386.54	3.7	385.1	388.8	23	490	359	311	670	13
199-K-32A	900	388.55	7.3	386.7	394.0	30	290	284	221	505	21
199-K-22	1,060	385.82	3.1	384.7	387.8	13	321	178	268	446	5
199-K-19	1,100	387.30	3.5	385.7	389.2	15	343	113	290	403	10
199-K-37	1,150	386.68	2.4	385.8	388.2	14	269	39	243	282	4
199-K-107A	1,350	390.52	3.4	389.1	392.5	13	330	59	294	353	10
199-K-34	1,390	390.25	3.5	388.8	392.3	25	433	76	399	475	19
199-K-106A	1,580	391.11	7.0	386.9	393.9	20	630	496	210	706	15
199-K-110A	1,660	393.29	2.3	392.6	394.9	12	437	707	330	1,037	19
199-K-13	1,680	391.11	2.3	390.1	392.4	17	291	121	240	361	6
199-K-109A	1,770	391.92	2.1	391.2	393.3	10	324	322	140	462	25
199-K-11	1,780	390.95	2.4	389.9	392.3	16	347	54	315	369	7
199-K-27	1,800	392.34	3.1	391.4	394.5	28	421	174	350	524	25
199-K-28	1,810	391.96	4.4	389.0	393.5	27	780	268	652	920	25
199-K-108A	1,820	392.10	4.6	390.3	394.9	13	443	111	380	491	11
199-K-29	1,850	392.46	4.1	389.7	393.7	23	321	119	271	390	19
199-K-23	1,890	392.68	1.9	391.8	393.7	13	606	234	518	752	10
199-K-30	1,910	392.67	2.6	391.6	394.2	27	506	188	410	598	23

Table 4-7. Water Level and Specific Conductance in 100-K Area Wells (Page 2 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μ S/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
199-K-111A	2,160	391.40	4.9	389.9	394.8	11	364	284	210	494	18
699-72-73	2,343	395.70	1.4	395.1	396.5	14	319	44	306	350	10
199-K-35	2,820	394.99	1.1	394.5	395.6	12	330	85	307	392	5
199-K-36	3,100	395.51	1.3	394.8	396.1	13	513	469	334	803	6
699-78-62	5,220	393.57	0.8	393.1	393.9	11	364	52	334	386	5
699-70-68	6,660	397.67	0.7	397.4	398.1	11	324	183	237	420	5
699-73-61	9,310	397.57	0.6	397.2	397.8	12	344	146	274	420	6
<i>Wells with open intervals significantly below the water table:</i>											
199-K-32B	900	396.77	2.2	395.7	397.9	15	387	93	360	453	5
Notes: Wells are listed in order of increasing distance from the river shoreline, as defined by low river stage. Data are representative of conditions between January 1, 1994 and August 30, 1995. Data source: HEIS.											

Table 4-8. Aquifer Slug Test Results for 100-K Area Wells

Well	Hydraulic Conductivity cm/sec	Hydraulic Conductivity ft/day
K-32A	0.028	80
K-33	0.007	19
K-34	0.024	68
K-35	0.043	124
K-36	0.030	87
K-37	0.051	145

Notes;

1. All wells screened in Ringold Unit E.
2. Data from 100-KR-4 LFI report (DOE-RL, 1994b)

Table 4-9. Physical Properties for Aquifer Sediments in the 100-K Area (Page 1 of 2)

Well Number/ Depth Interval m (ft)	Designation	Specific Gravity g/cm ³	Bulk Density gm/cm ³	Porosity %	K, Saturated cm/sec	Sediment Description
K-106A; 26.98-27.13m (88.5-89ft)	aquifer	2.7	2.2	18.4	2.55E-05	Sandy GRAVEL, Ringold E
K-106A; 38.35- 38.51 m (125.8-126.3 ft)	aquifer	2.7	2.2	17.6	1.45 E-06	Silty Gravelly SAND; Ringold E
K-106A; 49.88-50.03m (163.6-164.1)	aquitard	2.7	1.8	31.4	2.17 E-08	Sandy SILT; Ringold Upper Mud
K-107A; 25.76-26.22m (84.5-86ft)	aquifer	NA	NA	NA	1.18 E-03	Sandy GRAVEL, Ringold E
K-109A; 11.89-12.5m; (39.0-41.0ft)	vadose	2.68	NA	NA	NA	Sandy GRAVEL, Ringold E
K-109A; 18.75-19.21m, (61.5-63 ft)	vadose	2.68	2.0	24.6	3.27 E-04	Sandy GRAVEL, Ringold E
K-109A; 35.79-36.10m (117.4-118.4 ft)	aquifer	2.8	2.0	30.7	3.71 E-04	Silty sandy GRAVEL, Ringold E
K-109A; 44.21-44.82m (145-147 ft)	aquifer	2.8 (est)	2.0	29.8	4.27 E-04	Silty sandy GRAVEL, Ringold E
K-109A, 47.2-47.8 m (154.8-156.8 ft)	aquitard	2.8	1.9	32.7	1.21 E-04	CLAY, Ringold Upper Mud
K-109A; 50.52-51.13m (165.7-167.7 ft)	aquitard	2.6	1.9	26.1	3.40 E-08	CLAY, Ringold Upper Mud
K-110A; 12.16-12.77m (39.9-41.9 ft)	vadose	2.69	2.1	20.8	3.22 E-03	Silty Sandy GRAVEL, Ringold E
K-110A, (23.58-24.19m (77.35-79.35 ft)	aquifer	2.67	2.0	24.3	1.17 E-03	Sand, Ringold E
K-111A, 18.57-19.18 m (60.9-62.9 ft)	vadose	2.67	1.8	32.7	1.45E-04	Sandy GRAVEL, Ringold E

Table 4-9. Physical Properties for Aquifer Sediments in the 100-K Area (Page 2 of 2)

Well Number/ Depth Interval m (ft)	Designation	Specific Gravity g/cm ³	Bulk Density gm/cm ³	Porosity %	K, Saturated cm/sec	Sediment Description
K-111A, 24.85-25.0 (81.5-82.0 ft)	aquifer	2.7	2.4	10.3	8.8 E-06	Sandy GRAVEL, Ringold E
K-111A, 37.32-37.46 m (122.4-122.9 ft)	aquifer	2.65	2.1	19	3.45 E-04	Silty sandy GRAVEL, Ringold E
K-111A, 42.68-42.84 (140-140.5 ft)	aquifer	2.7	1.6	41.7	9.69 E-04	Sandy GRAVEL, Ringold E
K-111A, 44.45-44.60 m (145.8-146.3 ft)	aquifer	2.67	2.0	23.6	2.37 E-05	Sandy GRAVEL, Ringold E
K-111A, 47.29-47.59, (155.1-156.1 ft)	aquitard	2.68	1.7	37.6	2.15 E-04	Sandy silt, Ringold upper mud

Source: Borehole Data Package for the 100-K Area Ground Water Wells for CY 1994 (Williams, 1994).

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5.0 100-HR-3 OPERABLE UNIT

The 100-HR-3 Operable Unit includes two plutonium production reactor areas--the 100-D/DR and 100-H Areas--and the adjacent 600 Area (Figure 5-1). The entire area is included as a single groundwater operable unit because of similar hydrogeologic conditions, common groundwater/river interaction issues, and the probability that the two reactor areas are linked by groundwater flow paths.

The 100-HR-3 Operable Unit is situated in the horn of the Hanford Reach segment of the Columbia River. The Hanford Reach is used extensively by fall chinook salmon as spawning ground. Protecting this natural resource from Hanford contamination is a principal issue in remediation decisions.

This section describes aspects of the conceptual site model (CSM) that are common to the entire 100-HR-3 Operable Unit. Separate sections follow that describe the 100-D/DR and 100-H reactor areas in greater detail.

5.1 CONTAMINATION ACROSS THE HORN

Groundwater flow paths across the 100-HR-3 Operable Unit are illustrated by the water table contours shown in Figure 5-2. Groundwater generally flows along pathlines oriented perpendicular to the contours. The distribution of chromium is also shown in Figure 5-2. In areas with no monitoring wells, inferred groundwater flow patterns have been used to help guide the shape of the concentration contours.

Groundwater flow paths inferred from water table elevation maps support the idea that contamination from the 100-D/DR Area has migrated northeastward across the horn toward the 100-H Area. Sampling results from two 600 Area monitoring wells, which are located approximately one-half mile (0.8 km) west of the 100-H Area, reveal elevated concentrations of chromium in the groundwater. The concentrations are higher than concentrations currently observed in wells near 100-H Area liquid waste disposal facilities. There are no known sources of contamination near the two 600 Area wells. Thus, the chromium detected in these wells is believed to represent a plume that has migrated across the horn from the 100-D/DR Area.

5.2 SOURCE INVESTIGATIONS IN THE 600 AREA

One source operable unit, the 100-IU-4 Sodium Dichromate Barrel Landfill, is located in the 600 Area that separates the 100-D/DR and 100-H reactor areas (see Figure 5-1). The landfill is a shallow depression that was used for disposal of crushed 55-gallon drums that held sodium dichromate stock material. A monitoring well (699-91-46A) was installed in 1992 adjacent to the landfill on the downgradient side. Chromium concentrations for filtered samples from the well average 12 $\mu\text{g/L}$, which is close to the method detection limit and below the maximum

contaminant level (MCL) standard of 50 $\mu\text{g/L}$. The landfill is not considered a likely source for the chromium plume that is approaching the 100-H Area from the west (see Figure 5-2) for two reasons: no significant contamination was found in groundwater near the landfill site and groundwater flow would have carried contamination to the south of the 100-H Area.

The site was investigated and remediated under an expedited response action (DOE-RL, 1993; EPA, 1996b). Approximately 5,000 crushed barrels were removed from the site. No significant contamination was found in soils adjacent to the landfill.

5.3 CHROMIUM IN RIVER SUBSTRATE PORE WATER

The Hanford Reach along the 100-HR-3 Operable Unit is heavily used as spawning ground for fall chinook salmon. This segment of the river offers suitable habitat for the salmon to construct redds (nests of egg pockets). Suitable habitat requires a combination of appropriate riverbed sediment grain size and induration, river currents, water chemistry, and other less well-defined parameters that cause salmon to spawn where they do (Dauble and Watson, 1990). Recently, attention has been directed at identifying potential degradation of spawning habitat because of contamination from Hanford Site sources (Geist et al., 1994). Degradation may be caused by contamination that moves into the river environment from the Hanford Site, as well as from the opposite river bank and from upstream sources.

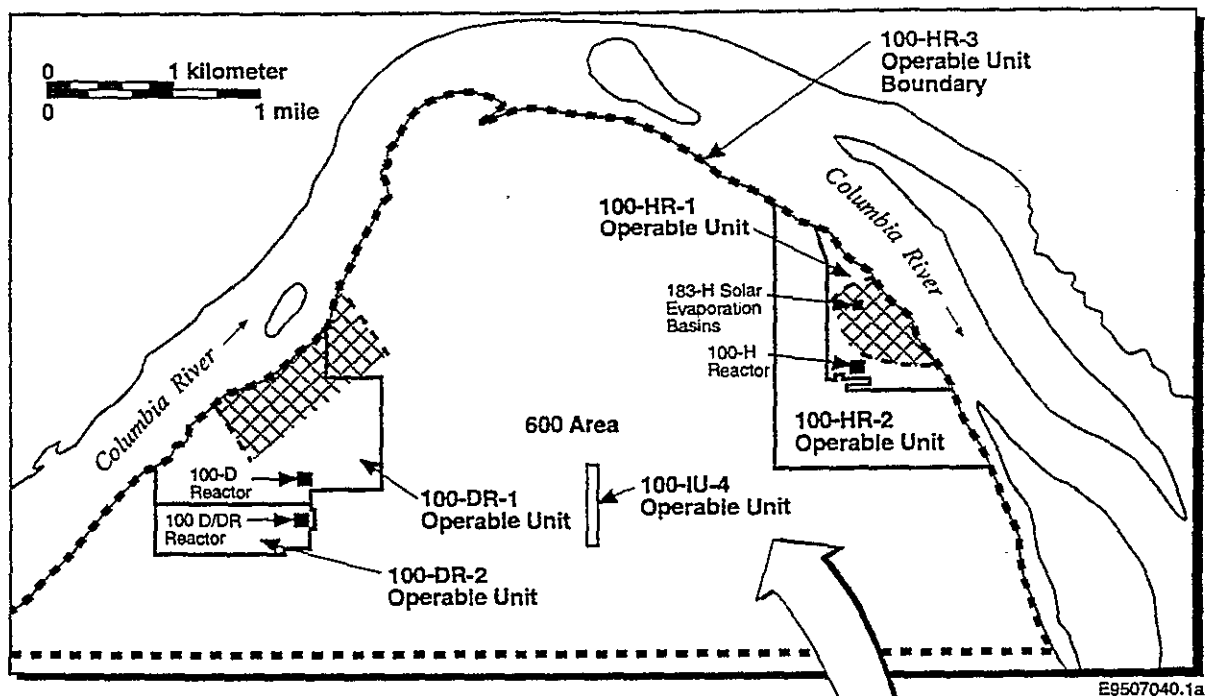
Spawning occurs in the Hanford Reach during October and November of each year, as documented by aerial observation and photography. A diver-assisted sampling project along the 100-H shoreline in March and April 1995 revealed chromium in spawning habitat at two locations (Hope and Peterson, 1996a). The concentration of hexavalent chromium exceeded the EPA criterion for protection of freshwater aquatic organisms (11 $\mu\text{g/L}$), with a maximum observed concentration of 130 $\mu\text{g/L}$. While these results are not definitive regarding all areas adjacent to 100-H where river substrate habitat might be exposed to chromium, the results do provide direct evidence at a limited number of sites.

A more comprehensive survey of the 100-D/DR Area was completed during October and November 1995 (Hope and Peterson, 1996b). River substrate pore water samples were collected at fifty nearshore transects, equally spaced along the entire 100-D/DR shoreline. Pore water samples were obtained from an 18-in. depth (46 cm) in the substrate at two sites along each transect. Because the riverbed slopes downward with increasing distance offshore, the two sites represent different depths in the aquifer—the first is approximately 5 ft (1.5 m) below the top of the aquifer (i.e., the water table) and the second approximately 10 ft (3 m) below.

Water samples also were collected from the aquifer along the shoreline by installing plastic sampling tubes using drive-point methods. Depths for the sampling ports were chosen such that the shoreline sampling tubes and the pore water sampling offshore monitored the same elevations in the aquifer (see Figure 2-4, which illustrates this relationship).

Figure 5-3 summarizes the 100-D/DR Area results and illustrates how contamination data from wells and shoreline sampling can be integrated with river habitat characteristics to describe the contamination issue along the pathway from source areas to potential receptors. Contaminant plumes, as defined by data from monitoring wells and shoreline aquifer samples, help identify nearshore river areas where potential risk is likely to be greatest. River locations actually used by sensitive receptors (e.g., salmon redds), or suitable for use (e.g., gravelly sediments), are identified and assessed relative to the nearshore areas suspected of being contaminated. Finally, samples collected from the very environment used by sensitive receptors (e.g., pore water samples from riverbed sediment) provide direct evidence for contamination at the point of exposure.

Figure 5-1. Index to the 100-HR-3 Operable Unit



Legend:

Approximate area of chromium contamination in groundwater to be addressed by interim remedial measure

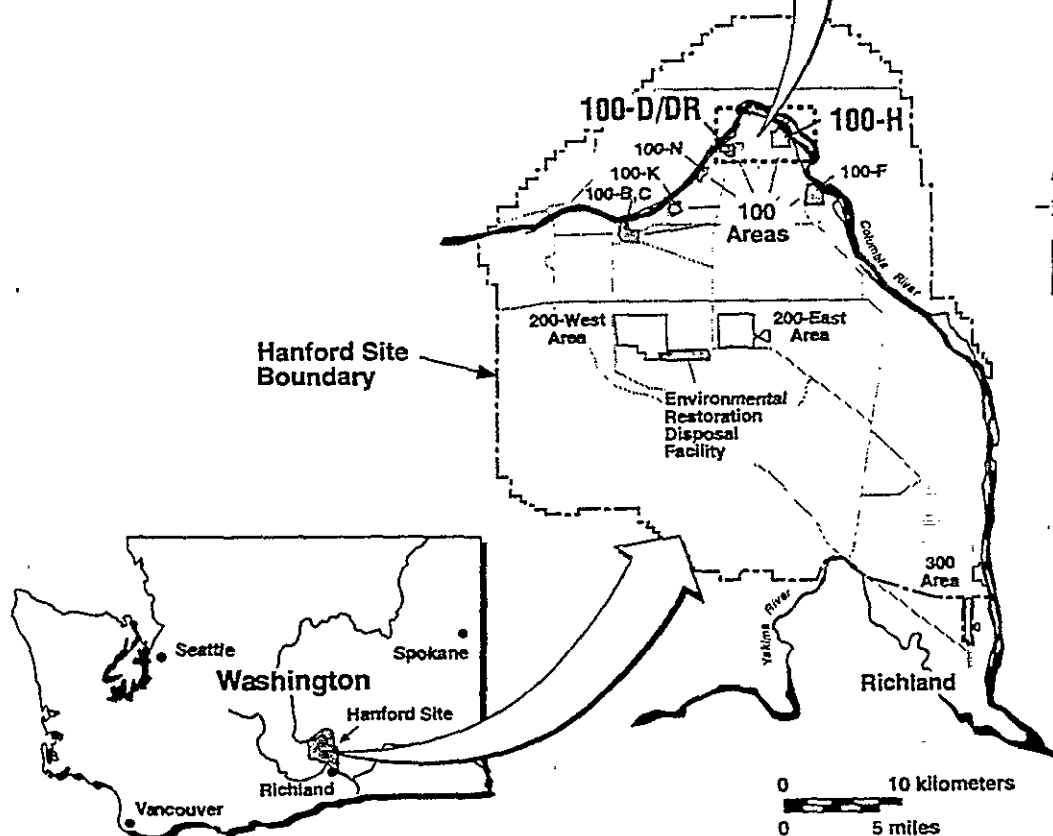


Figure 5-2. Chromium Distribution Across the 100-HR-3 Operable Unit

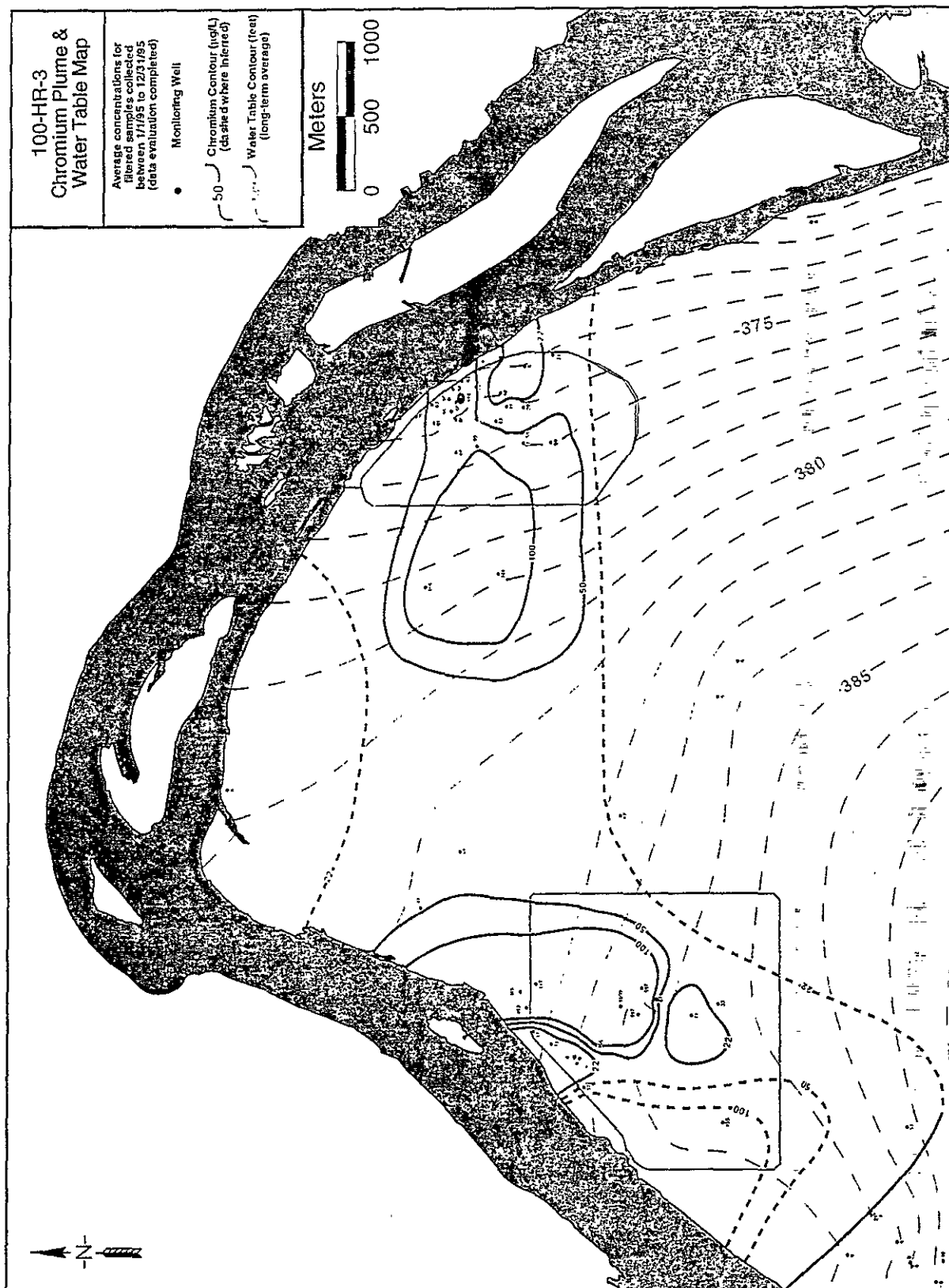
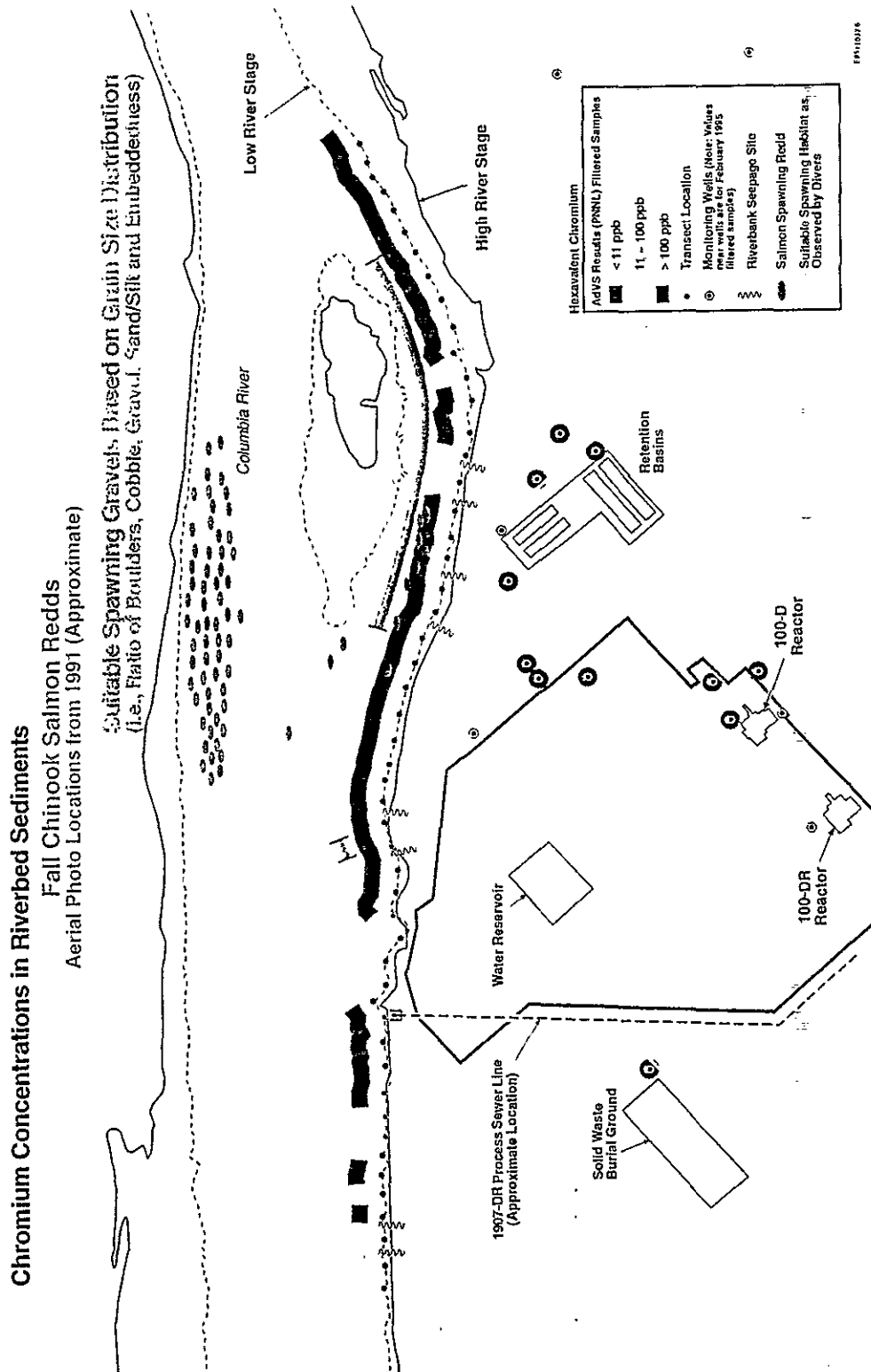


Figure 5-3. Chromium in Groundwater and Along the Shoreline, 100-D/DR Area



6.0 100-HR-3 OPERABLE UNIT: 100-D/DR AREA

The 100-HR-3 Operable Unit includes the groundwater underlying the 100-D/DR Area and adjacent areas where contaminated groundwater may pose a risk to human and ecological receptors. Examples of adjacent areas are the riverbed, where groundwater may upwell into sediments that form habitat for aquatic life, and locations where water seeps from the riverbank during low river conditions. Figure 6-1 is an index map for the 100-D/DR Area that shows the locations of groundwater monitoring wells and facilities/waste sites discussed in the text.

The following sections describe contaminants of concern, their distribution, how they change with time, and the hydrogeologic framework through which they move.

6.1 CONTAMINANTS OF CONCERN

Contaminants of concern are chemical and radiological constituents that pose a risk to human and/or ecological receptors. Numerous regulatory requirements, such as the U.S. Environmental Protection Agency's (EPA) drinking water standards (40 CFR 141 "maximum contaminant levels" [MCL]) and ambient water quality criteria (AWQC) for protection of freshwater aquatic organisms, help identify which constituents are of concern.

A limited field investigation (LFI) for the 100-HR-3 Operable Unit identified contaminants of potential concern based on a limited set of data collected in 1992 and 1993. These constituents were used in a qualitative risk assessment, the results of which included recommendations regarding interim remedial measures (IRM). The contaminants of concern, conclusions, and recommendations contained in the LFI report (DOE-RL, 1994c) are as follows:

Operable Unit	Human Health Risk	Ecological Risk	LFI Conclusion and Recommendation
100-HR-3: 100-D/DR Area	Chromium Nitrate Strontium-90 Tritium	Chromium Sulfide	An IRM is not indicated on the basis of human health or ecological risk. Continue the RI/FS process. Note: Subsequent analysis of data concluded that ecological risk from chromium warranted interim remedial measures.

Source: Limited Field Investigation Report (DOE-RL, 1994c)

These contaminants of concern continue to be tracked primarily by semiannual sampling of wells since the LFI phase of the remedial investigation/feasibility study (RI/FS). As sufficient information becomes available to demonstrate that a constituent is no longer of concern with respect to human health and ecological risk, it is typically removed from the monitoring

schedule. However, data for some discontinued contaminants of concern may continue to accumulate, because the constituent is part of a grouped analysis (e.g., an analysis of metals by inductively coupled plasma [ICP]).

Characterization and focused feasibility study (FFS) activities that continued during the final phases of the LFI resulted in a revised assessment of ecological risk because of hexavalent chromium in groundwater near the Columbia River. This led to a decision to proceed with interim remedial measures (IRM) to address chromium contamination (DOE-RL, 1995a and EPA, 1996a). A remedial design/remedial action (RD/RA) work plan (DOE-RL, 1996) describes this IRM, which includes the 100-KR-4 Operable Unit also.

6.1.1 Summary of Current Groundwater Contamination Levels

Table 6-1 presents recently observed concentrations for contaminants of potential concern identified during the LFI, as well as additional waste and water quality indicators. This table includes all results contained in the Hanford Environmental Information System (HEIS) database for sampling more recent than January 1, 1995 (generally inclusive of sampling conducted through January 1996). Semiannual sampling has been the norm since the last half of 1994, so this summary is generally based on two or three sampling events per well.

Initial data evaluation processing has been completed on the entire data set summarized in Table 6-1 (i.e., assigning common units, removing duplicate entries, and correcting known errors in reported results). The full data evaluation process has been completed for chromium, nitrate, strontium-90, tritium, and specific conductance (see Ford and Denslow, 1996 for a description of the data evaluation process for data extracted from HEIS).

The list of constituents that currently exceed regulatory standards is similar to the list of contaminants of potential concern identified during the LFI, with some exceptions. Chromium, nitrate, strontium-90 (and gross beta activity), and tritium remain above standards in several wells. Sulfide was removed from the list of contaminants of concern during the focused feasibility study (DOE-RL, 1995g), since most analytical results indicated nondetection. Additional constituents that are above MCL standards are aluminum, iron, manganese, and possibly lead, although analysis for lead has been limited to two samples, with a nondetect and slightly elevated result.

Table 6-2 identifies the 100-D/DR Area wells in which various constituents included in Table 6-1 exceed standards. Chromium and nitrate are the most widespread contaminants, as indicated by the number of wells in which these constituents exceed standards.

6.1.2 Sources for Contamination in Groundwater

Figure 6-1 shows the principal surface facilities associated with liquid waste disposal to the soil column. A detailed description of these waste-generating facilities is contained in the 100-D Area Technical Baseline Report (Carpenter, 1993). A description of how the plutonium production reactors operated is presented in the "Hazards Summary Report" for the production

reactor plants (General Electric, 1963). Both documents provide comprehensive background material for interpreting the origin of groundwater contamination. The source information contained in the following summary is derived from those documents, unless otherwise cited.

6.1.2.1 Coolant water retention basins. The 107-D coolant water retention basins are responsible for introducing a significant amount of chromium to the soil column and groundwater. These basins received enormous volumes of relatively low concentration (less than 700 $\mu\text{g/L}$) chromium-bearing coolant water. Because of significant leakage from the basins (Ryan, 1963), mounds 3 to 6 m (10 to 20 ft) higher than the natural water table were created (Brown, 1963). During mounding, riverbank seepage of groundwater increased significantly, with hot springs readily visible during low river stage (Brown, 1963). As a result of the radial flow pattern created by mounding, chromium was distributed widely beneath the 100-D/DR Area.

A 1967 test evaluated the capacity of natural soils to receive reactor coolant effluent directly, without the water first passing through a retention basin (Eliason and Hajek, 1967). Coolant was diverted at a rate of approximately 27,000 gpm from the 105-D reactor to an open trench adjacent to the retention basins (see Section 6.1.2.2). A significant mound was created during the four-month test, as were riverbank springs. The test showed the soil column could accommodate infiltration at the test rate. It also showed the mound on the water table dissipated quickly after the test stopped.

Mounding beneath the retention basins during normal operations was probably not as extensive as during the 1967 test, although it is believed to have been sufficient to influence flow patterns. Some groundwater from the 100-D/DR Area flowed northeast and east across the "600 Area" because of mounding and the natural configuration of the water table.

After operations ceased in the mid-1960s and the mounds dissipated, chromium was likely present in the residual moisture left in the normally unsaturated part of the soil column. This residual chromium is expected to continue to diffuse downward at a low rate, contributing a small but continual supply of chromium to groundwater (Peterson and Connelly, 1992).

6.1.2.2 Liquid waste disposal trenches. These soil column disposal facilities received used reactor coolant that had been highly contaminated by fuel element ruptures. They were located immediately to the east of the retention basins and represent a primary source for radionuclide and chromium contamination in groundwater.

Many radionuclides are adsorbed by sediments in the soil column. This was a primary advantage of using soil column disposal for highly contaminated coolant effluent (instead of direct river discharge via retention basins, as was normal for the reactor coolant effluent stream). However, when a mound was present beneath the retention basins, it is likely that the soil column was not able to scavenge radionuclides from the infiltrating coolant as when a natural water table existed. This is because the rate of groundwater flow was much faster, and fine

materials (the major adsorbers of radionuclides) were washed out of the sediments. Consequently, radionuclide movement to the river via groundwater flow and riverbank seepage may still have been appreciable.

6.1.2.3 Miscellaneous disposal facilities near reactors. Various acid solutions, which included nitric, chromic, and sulfuric acids, were used to decontaminate equipment associated with reactor operations. These solutions, which picked up radionuclides and various metals, were typically discharged to small soil column disposal facilities such as cribs, french drains, and trenches near the 105-D and 105-DR reactor buildings. While involving much smaller volumes than coolant water discharge, the solutions typically contained considerably higher chromium concentrations.

Liquid waste "percolation" trenches (D-1A and D-1B Trenches in Figure 6-1) received liquid effluents and sludge from the fuel storage basins, which were located in the reactor buildings. These trenches are sources for chromium and for radionuclides, including tritium.

6.1.2.4 Summary of source operable unit high-priority waste sites. Tabular summaries of waste sites were prepared to support records of decision for source operable units. These summaries include the waste site designator, physical characteristics, and contaminants that may be associated with the site. The summaries were originally presented in the proposed plans for the 100-DR-1 and 100-DR-2 Operable Units (DOE-RL, 1995h and DOE-RL, 1995i), and are included in this report as Tables 6-3 and 6-4.

6.1.2.5 Summary of liquid waste sites that received chromium. Table 6-5 lists known liquid waste disposal sites that involved chromium within the 100-D/DR Area. The table has been assembled from available information gathered during the RI/FS. It draws heavily on information contained in the 100-D/DR Area Technical Baseline Report (Carpenter, 1963).

6.2 CONTAMINANT DISTRIBUTION MAPS AND TREND CHARTS

Average concentrations for chromium, strontium-90, and nitrate for samples collected since January 1, 1995 have been plotted on maps to illustrate the distribution of contamination in 100-D/DR Area groundwater. The maps include water table contours for long-term average elevations, as estimated by measurements for the period from January 1, 1994 through August 30, 1995. Groundwater flow is generally oriented perpendicular to the contour lines.

The concentrations plotted are average values for data from HEIS that have undergone the full data evaluation process (Ford and Denslow, 1996). This process is intended to produce concentration values that represent aquifer conditions as accurately as possible. The average values presented do not include results considered nonrepresentative ("outliers") by the data evaluator. Chromium results are for filtered samples, because these data provide the best indicator for chromium that is dispersed by groundwater flow.

Supplemental data are available in the 100-D/DR Area to describe chromium contamination at multiple depths in the aquifer along the shoreline and in river substrate pore water. Samples

were collected during fall 1995 and are considered representative of the same general time period as the plume maps developed from monitoring well data. The shoreline sampling project results and interpretations are described in detail in Hope and Peterson (1996b). The following section includes a summary of the results.

6.2.1 Chromium Contamination

Figure 6-2 illustrates the chromium distribution considered representative of current conditions in groundwater, as interpreted using data from monitoring wells. The average concentrations plotted are for analyses of total chromium in a filtered sample. Of the two common valence states for chromium, the hexavalent form is soluble and the trivalent form insoluble (i.e., associated with particulate matter). Therefore, the results in Figure 6-2 are generally representative of hexavalent chromium, the form most toxic to aquatic organisms (Eisler, 1985).

Two general areas of contamination are apparent. The first is a reasonably well-defined plume that is the current target for interim remedial action involving a pump-and-treat system. The existence of a second, poorly defined plume is inferred from chromium contamination observed along the shoreline near the southwest boundary of the 100-D/DR Area.

6.2.1.1 Target plume addressed by pump-and-treat system. This plume extends northward from the 100-D reactor building to the retention basins and presumably on to the river. Based on water table gradients, some component of this plume may also continue along a northerly and northeasterly direction. The best candidate sources for chromium in this plume are near the 100-D reactor building. They include two trenches (waste sites 116-D-1A and 116-D-1B; see Table 6-6) as well as sodium dichromate storage and transfer facilities immediately north of the reactor building. It is assumed that the plume is continuous from the reactor building downgradient to the shoreline, although monitoring well coverage is insufficient to corroborate this. The relatively high levels of chromium observed in wells immediately downgradient of the retention basins are less likely to be associated with residual moisture from the basins, because the basins have been out of service since 1967.

Trend charts for near-river wells located within or adjacent to this plume are presented in Figures 6-3 and 6-4. Concentrations in wells 199-D8-54A and 199-D8-53 (Figure 6-3), which are located near the river, appear constant, although there is some indication that the most recent results may reflect the influence of unusually high river and water-table conditions during winter 1995/1996.

Wells located along the western boundary of the plume (199-D8-55, 199-D8-5, and 199-D8-4; Figure 6-4) show much lower concentrations than those within the plume. This zone of lower contamination is attributed to dilution by clean water disposed of in "D-Ponds," a facility that primarily received filter backwash from the 100-D/DR Area water treatment plant (Alexander, 1993). However, effluent disposal to the ponds stopped in June 1994, and the dilution effect is expected to disappear (Hartman, 1995a). The increasing chromium trend for well 199-D5-13 (Figure 6-4), which is located immediately upgradient of D-Ponds, provides evidence for a diminishing dilution effect. Water approaching this well probably contains chromium from

waste disposal near the 100-D reactor building. An increasing specific conductance trend in this well provides additional evidence that the groundwater underlying D-Ponds is no longer affected by disposal to the ponds.

Figure 6-5 shows trend charts for wells 199-D5-14, 199-D5-15, and 199-D5-16, which are located near the 105-D reactor building and the sodium dichromate storage facilities on the northern side of the building. Since their installation in 1992 as part of the limited field investigation, well 199-D5-14 has shown an increasing chromium trend, 199-D5-15 a decreasing trend, and 199-D5-16 a constant trend. Results for metals on unfiltered and filtered samples from these wells are very similar, in contrast to other wells constructed of stainless steel in the 100 Area. (For example, 199-D8-55 shows significant differences between unfiltered and filtered sample results [see Figure 6-3].) The explanation for differences among metals data for various wells remains enigmatic.

Wells 199-D5-14, 199-D5-15, and 199-D5-16 were used as extraction wells since the August 1994 startup of the pilot-scale treatability test for the 100-HR-3 Operable Unit (DOE-RL, 1995j). Each shows a consistent reduction in chromium concentrations for sampling more recent than January 1995, which may reflect the test's pumping operation (Figure 6-5). The pilot-scale test report (DOE-RL, 1995j) estimates that the amount of chromium contained in the plume is between 329 and 420 kg and that the test pump-and-treat system removed 29.9 kg as of November 1, 1995. As of August 1996, when the test was shut down, approximately 50 kg of chromium had been recovered. The pilot-scale test has, therefore, removed a significant amount of chromium from the aquifer near a suspected source area. Subsequent monitoring of the three extraction wells and the reinjection wells (199-D5-18 and 199-D5-19) will provide relevant data for evaluating the test's effect on plume characteristics.

6.2.1.2 Chromium contamination in the southwest corner of the 100-D/DR Area. The chromium plume map shown in Figure 6-2 uses dashed contour lines to indicate the possible existence of chromium in the area west of the 105-DR reactor building. This area of contamination is inferred through the use of data on chromium in groundwater collected at sampling locations along the shoreline (Hope and Peterson, 1996b). Figure 6-6 shows chromium concentrations for samples from aquifer sampling tubes along the river shoreline. Figure 6-7 shows chromium concentrations in samples of river substrate pore water.

Supporting the inference of a plume in this area is a single monitoring well (199-D2-6) that exhibits a fairly constant concentration of chromium, which has averaged 165 $\mu\text{g/L}$ over the last several years (see Figure 6-5). The area contains an identified source for chromium--a sodium dichromate transfer station where spillage and intentional disposal of washdown water occurred (Carpenter, 1993). The transfer station is listed in Table 6-5 as the 100-D-12 Sodium Dichromate Transfer Station. A second potential source is a process sewer line that extended from the vicinity of the 105-DR reactor west-northwest to an outfall on the shoreline (see Table 6-5, 1907-DR Outfall Structure). While there is no documentation for past sewer line leakage, the line is known to have carried chromium-laden effluent (Carpenter, 1993). Soil sampling around the outfall flume structure on the riverbank did not reveal any chromium contamination (Hope, 1996).

An additional hypothesis to explain the presence and source for chromium in the aquifer along the shoreline in this area is based on simulated flow patterns (M. P. Connelly, CH2M Hill Hanford, Inc., internal technical memorandum). During reactor operations, when groundwater mounds were present because of leakage from the retention basins, the natural flow pattern was altered (Brown, 1963; see Section 6.1.2.1 above). A water table map was constructed using limited historical data to simulate conditions during 1955, when the retention basins were in operation and a mound may have been present. Detailed data on a mound created during an infiltration test (Eliason and Hajek, 1967) was incorporated. The resulting simulation is shown in Figure 6-8.

The flow pattern suggested by the simulated conditions in Figure 6-8 could have moved chromium to the southwest corner of the 100-D/DR Area. Simulated flow lines pass over suspected sources near the reactor buildings, the process sewer, and the sodium dichromate transfer stations and distribution lines. The chromium observed currently along the shoreline may have been transported by this flow pattern during reactor operating years. Chromium observed in the only monitoring well in this area (199-D2-6) could be explained also as the tail end of a plume that traveled along the simulated flow paths.

6.2.2 Strontium-90

Strontium-90 concentrations are shown in Figure 6-9. This common reactor area contaminant is elevated above the MCL standard of 8 pCi/L in only a single well (199-D5-12) near the 105-D reactor. Concentrations in this well have ranged between 30 and 45 pCi/L since 1992. The well is located within the influence of the recently-completed extraction/injection network for the pilot-scale test. Sampling of 199-D5-12, however, has not been sufficiently frequent to identify any influence of the test on strontium-90 concentrations.

6.2.3 Nitrate

The distribution of nitrate is shown in Figure 6-10. Nitrate is elevated above the 45,000 µg/L MCL standard in the vicinity of the 105-D reactor building, the retention basins, and the liquid waste disposal trench. It is also elevated in well 199-D2-6, which is located adjacent to a solid waste burial ground (see Table 6-5, waste site "118-D-2"). Figure 6-11 shows trends for monitoring wells within the area targeted by the interim remedial measure pump-and-treat system. Figure 6-12 shows trends for wells near the 105-D reactor building and the solid waste burial ground.

Nitrate concentrations are anomalously low for the area downgradient of D-Ponds, which is probably a result of dilution by the clean effluent disposed of to the ponds prior to 1992.

6.3 HYDROGEOLOGY

This section describes the framework through which contaminants may be transported by groundwater movement. The following sections describe the lithologies of the stratigraphic units

and the saturated and unsaturated zones, as well as the physical properties of the various hydrostratigraphic units.

6.3.1 Hanford and Ringold Stratigraphic Units

The most important stratigraphic units underlying the 100-D/DR reactor area are the Hanford formation and the Ringold Formation. Figure 6-13 is a geologic cross section oriented perpendicular to groundwater flow. Figure 6-14 shows a cross section oriented approximately parallel to the Columbia River. These cross sections show the Hanford-Ringold contact, graphically display sediments recovered during drilling of the groundwater monitoring wells, and show the range in depth to groundwater during the period from January 1, 1994, to August 30, 1995. (See Figure 6-1 for the surface trace of cross sections shown on Figures 6-13 and 6-14.) See Lindsey and Jaeger (1993), for a detailed description of the geologic section to the top of basalt.)

The contact between Hanford formation gravel and Ringold Formation Unit E is based primarily on the lithology and color of the sand fraction. Hanford formation sands have a higher basalt content than Ringold Formation sands. Also, the Hanford formation sands are commonly salt and pepper (white and black), while the Ringold Formation sands are reddish-brown to yellow-brown. The Ringold Formation materials are generally denser and may be locally cemented (Lindsey and Jaeger, 1993).

6.3.1.1 Hanford formation. The Hanford formation in the 100-D/DR Reactor Area is dominated by sandy gravel and gravelly sand, with local sandy and silty interbeds (Figures 6-13 and 6-14). The Hanford formation is 12.2 to 15.2 m (40 to 50 ft) thick throughout most of the 100-D/DR Reactor Area and thickens to over 23 m (76 ft) around the DR reactor in wells D5-17 and D5-18.

6.3.1.2 Ringold Formation. The Ringold Formation in the 100-D/DR Reactor Area includes both Unit E and the underlying upper mud facies. Unit E ranges in thickness from a maximum of about 15.8 m (52.1 ft) in D5-15 to pinched out completely in D8-54B and D8-55 near the Columbia River. It is composed of coarse, dense, silty gravel and gravelly sand.

The Ringold upper mud underlies Unit E in much of the 100-D/DR Reactor Area and is in contact with the Hanford formation in wells D8-54A/B and D8-55 (see section B-B', Figure 6-14). The upper mud is characterized by silt and sandy silt with sandy interbeds. No wells in the 100-D/DR Reactor Area completely penetrated the upper mud; however, wells drilled to basalt in the 100-N and 100-H areas indicate the upper mud is approximately 80 m (262 ft) thick (Lindsey and Jaeger, 1993).

6.3.2 Vadose Zone and Uppermost Aquifer

The vadose zone ranges in thickness from approximately 26.2 m (86 ft) in D5-14 to 14.3 m (47 ft) in D8-53 near the Columbia River (see Figures 6-13 and 6-14). These figures show the top of the saturated zone, the water table, is located in the Ringold Formation Unit E, but it may

locally be in the lowermost Hanford formation. It follows that the uppermost aquifer is mostly within the Ringold Formation Unit E. Where the Hanford formation is in contact with the Ringold upper mud, the uppermost aquifer is completely within the Hanford, because the Ringold upper mud acts as an aquitard.

The saturated thickness of the uppermost aquifer appears to range from 2.4 m (8 ft) in D5-12 to 7.9 m (26 ft) in D5-54B. This saturated thickness includes both Hanford formation and Ringold Formation Unit E. Some wells did not penetrate to the top of the upper mud.

Geologic sections A-A' and B-B' (Figures 6-13 and 6-14) show maximum and minimum groundwater elevations of the top of the uppermost aquifer, as measured in wells from January 1, 1994, to August 30, 1995. Wells near the Columbia River (199-D8-54A) vary up to 1.52 m (5.0 ft) in groundwater elevation, while wells inland (199-D5-19) vary as little as 0.15 m (0.5 ft). The range in groundwater elevation near the river is largely due to the effect of river stage.

Figure 6-12 shows the elevation of the water table, as developed from average elevations in wells measured from January 1, 1994, to August 30, 1995. The flow direction varies from northwest to north, with a gradient of 0.0006.

The presence of a slight vertical (upward) hydraulic gradient is likely in the 100-D/DR Reactor Area based on hydrographs of transducer data from 199-D8-54A and 199-D8-54B (Figure 6-5). All the existing groundwater monitoring wells, with the exception of 199-D8-54B, were screened in the unconfined aquifer. Well 199-D8-54B was screened from elevation 91.2 to 94.2 m (299 to 309 ft) in the first producing horizon reached after penetrating into the upper aquitard (Ringold upper mud). The adjacent 199-D8-54A was screened from elevation 111.7 m (366.4 ft) to 118.1 m (387.5 ft) in Hanford formation gravel (Table 6-6).

The average groundwater elevation in 199-D8-54B was approximately 0.18 m (0.6 ft) higher than the average elevation in adjacent 199-D8-54A. In addition, from 1992 to the present, quarterly water elevations in 199-D8-54B (the confined aquifer well) generally were higher than in 199-D8-53A (the unconfined aquifer well). However, water table elevations in 199-D8-54A are occasionally higher than 199-D8-54B. The range in groundwater elevations in 199-D8-54B was 2.37 m (7.8 ft), compared to a 1.52 m (5 ft) range in 199-D8-54A. Water level variations in 199-D8-54A are probably linked to river stage, while those in 199-D8-54B may be attributed to river loading and barometric effects.

6.3.3 River Influence on Monitoring Wells

Water level elevations and specific conductance are used to qualitatively evaluate the influence the river has on monitoring wells. Table 6-7 summarizes water level elevations and specific conductance for each 100-D/DR Area well and shows the well's distance inland from the river's low-water shoreline. The wells are separated into two groups in the table: (1) those that have screened or perforated open intervals that include the water table and (2) those that are open at depths in the aquifer well below the water table.

Data for Table 6-7 were extracted from HEIS in the form of depth-to-water measurements. These values were combined with recent top-of-casing surveys, using either results from an extensive 1993 U.S. Army Corps of Engineers survey, or, when Corps data are not available, results from a recent ICF Kaiser Hanford, Inc., survey. These surveys are referenced to baseline monuments, the locations of which were re-established by the Corps in 1993. All data are referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

The average water level elevation is for data obtained during the period from January 1, 1994, through August 30, 1995. This average represents long-term conditions over slightly more than a seasonal cycle. The range between minimum and maximum water level elevations provides a measure of the degree to which river stage fluctuations influence the well. The range is also influenced by the degree to which the aquifer segment intercepted by the well is confined. In response to river fluctuations, more-confined segments produce greater changes in well water levels.

Values for specific conductance are also included in Table 6-7. Specific conductance, which varies with the amount of dissolved salts in the groundwater, can be used to identify water of various origins. River water is typically in the range of 120 to 140 $\mu\text{S}/\text{cm}$. Groundwater from the Hanford gravels is approximately 400 $\mu\text{S}/\text{cm}$, while water from the Ringold Formation appears to be approximately 300 $\mu\text{S}/\text{cm}$, although data to support the latter are limited. Given these contrasts, specific conductance is useful in helping to describe the interaction between river water and groundwater. However, where contamination is present, specific conductance may vary over a wide range, thus reducing its usefulness as a mixing indicator for natural waters.

6.3.4 Aquifer Properties

Slug tests were conducted in 11 wells in the 100-D/DR Reactor Area during the LFI. The results were analyzed in accordance with Bouwer and Rice (1976) and Bouwer (1989). Table 6-8 is a summary of hydraulic conductivities from slug test data collected from wells in the 100-D/DR Reactor Area (DOE-RL, 1994c). Hydraulic conductivities varied from 0.187 cm/sec (530 ft/d) in 199-D8-53 Ringold Unit E to 0.0035 cm/sec (10 ft/d) in 199-D5-16 and 199-D5-17 Ringold Unit E.

Short duration drawdown tests were conducted in 199-D5-14, -D5-15, -D5-16, -D5-17, -D5-18, and -D5-19 in 1994 to evaluate the potential production and injection wells for the 100-D Area chromate pilot scale pump-and-treat system. The hydraulic conductivities established from these tests ranged from 0.0296 cm/sec (84 ft/day) in 199-D5-18 to 0.0046 cm/sec (13 ft/day) in 199-D5-15. The hydraulic conductivities determined by slug tests were within an order of magnitude of the values determined from data collected during drawdown tests (see Table 6-8).

Additional drawdown tests were conducted in 1995 as part of the well selection process for the 100-HR-3 IRM. The duration of the tests was not adequate to determine hydraulic conductivity.

6.3.5 Physical Properties of Aquifer Materials

Table 6-9 is a summary of physical-properties testing on 14 samples collected from wells 199-D5-14, -D5-17, -D8-53, -D8-55, -D8-54A, and -D8-54B. Samples were collected from the Hanford formation, Ringold Formation Unit E, and Ringold Formation upper mud. Samples are classified by hydrogeologic designation (e.g., vadose), sediment description, and stratigraphic unit.

Figure 6-1. Wells and Principal Surface Facilities - 100-HR-3 (D/DR) Area

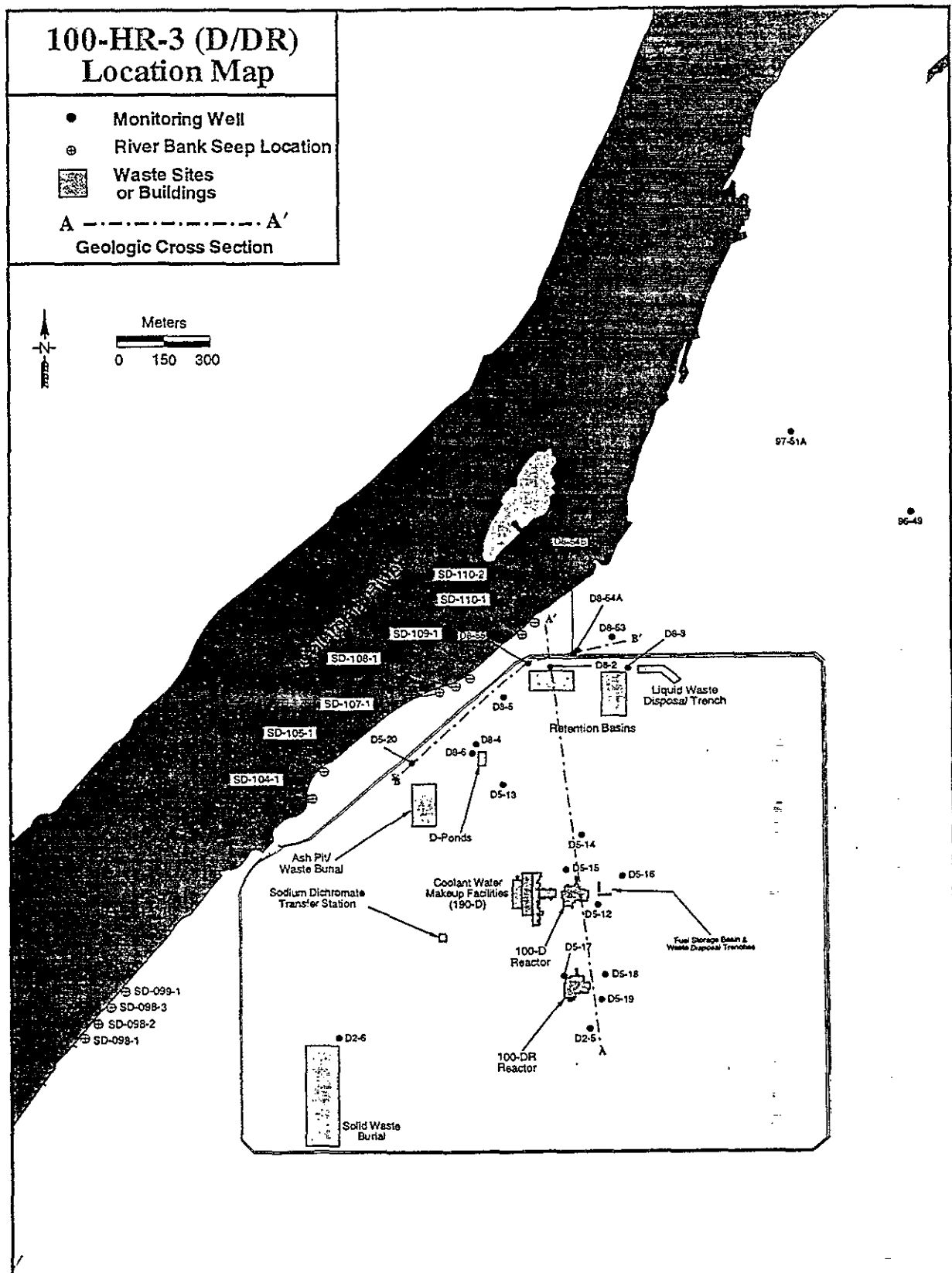


Figure 6-2. Chromium Distribution in the 100-D/DR Area

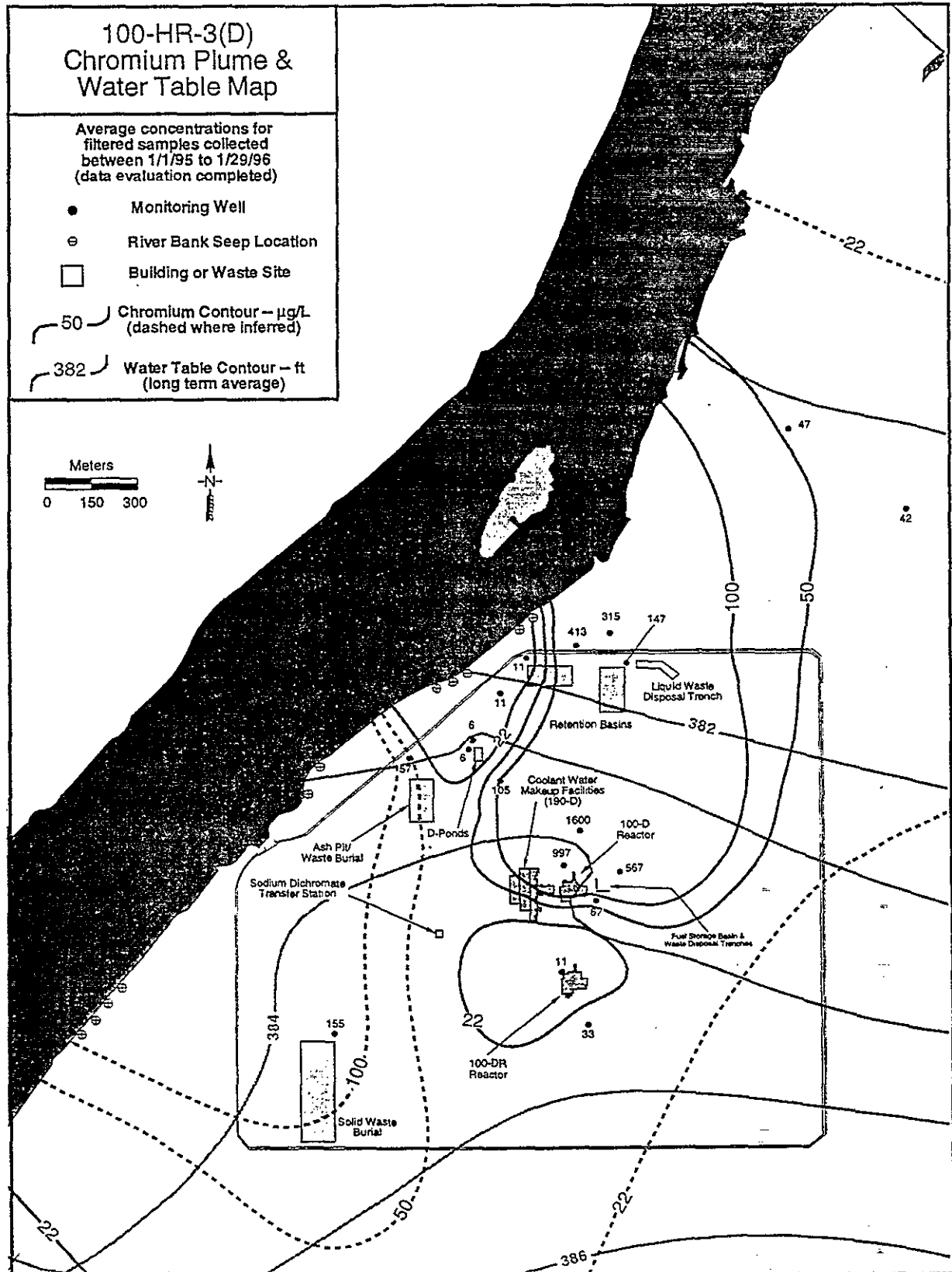


Figure 6-3. Chromium Trends in Selected 100-D/DR IRM Network Wells

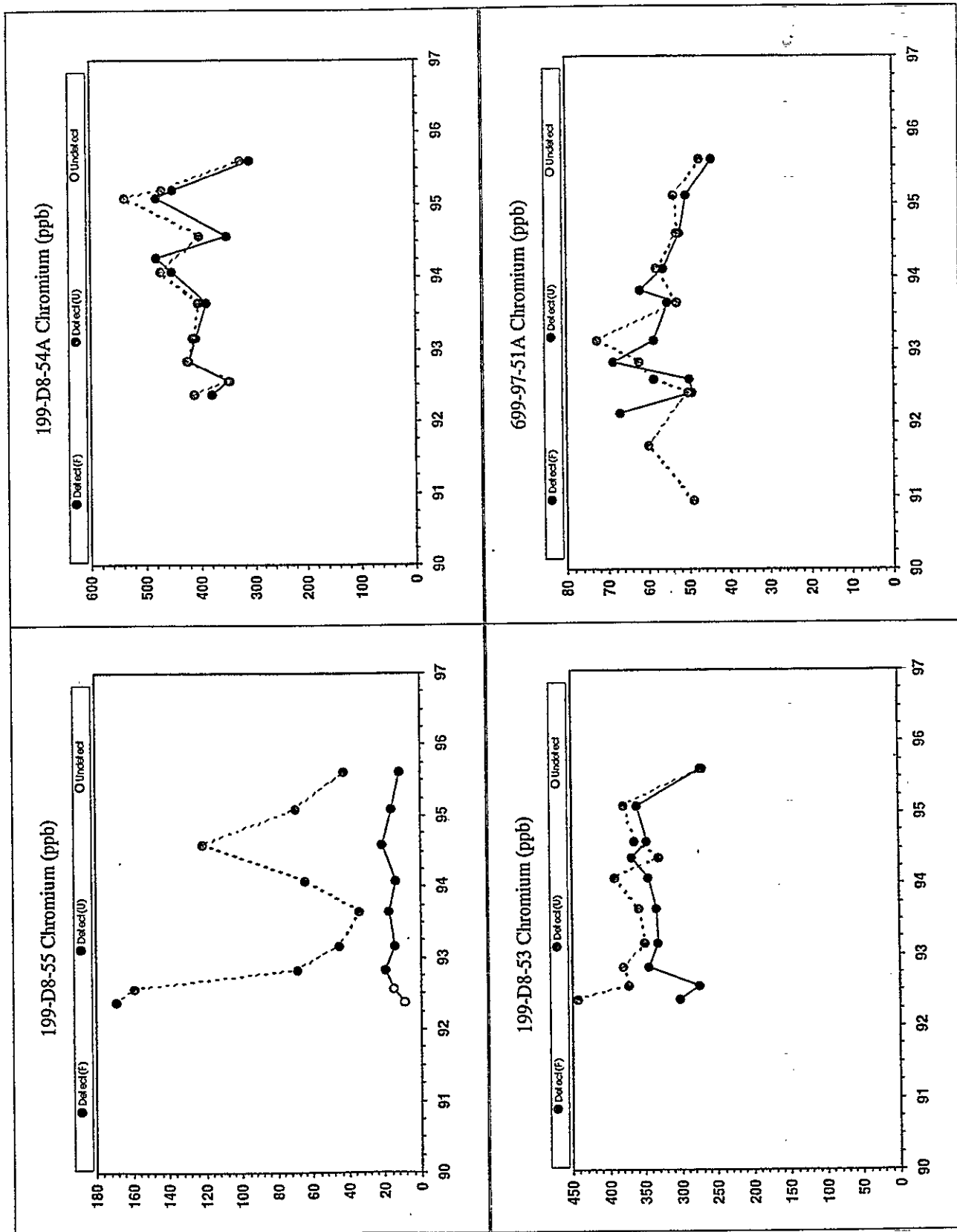
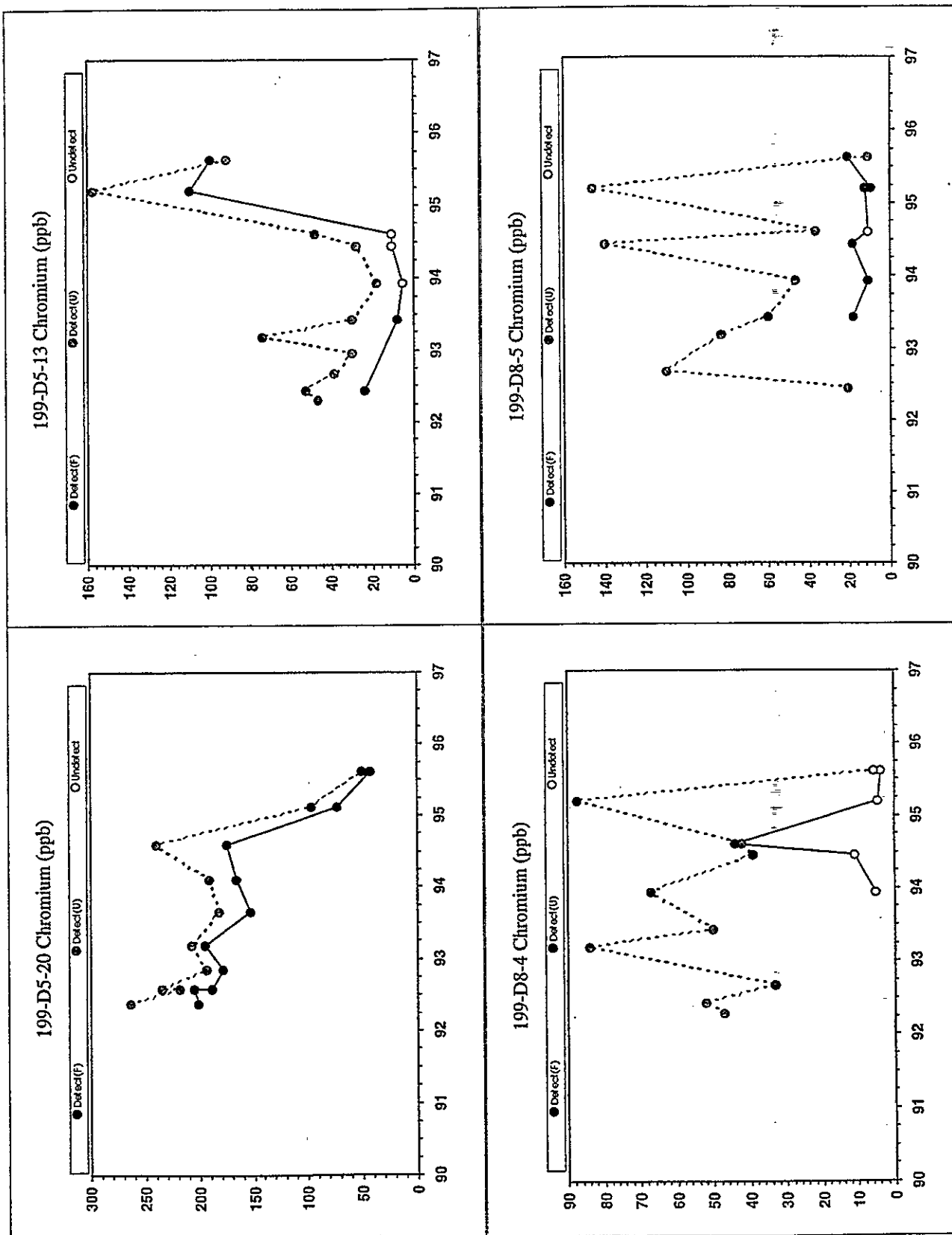


Figure 6-4. Chromium Trends in Selected 100-D/DR Area Near-River Wells



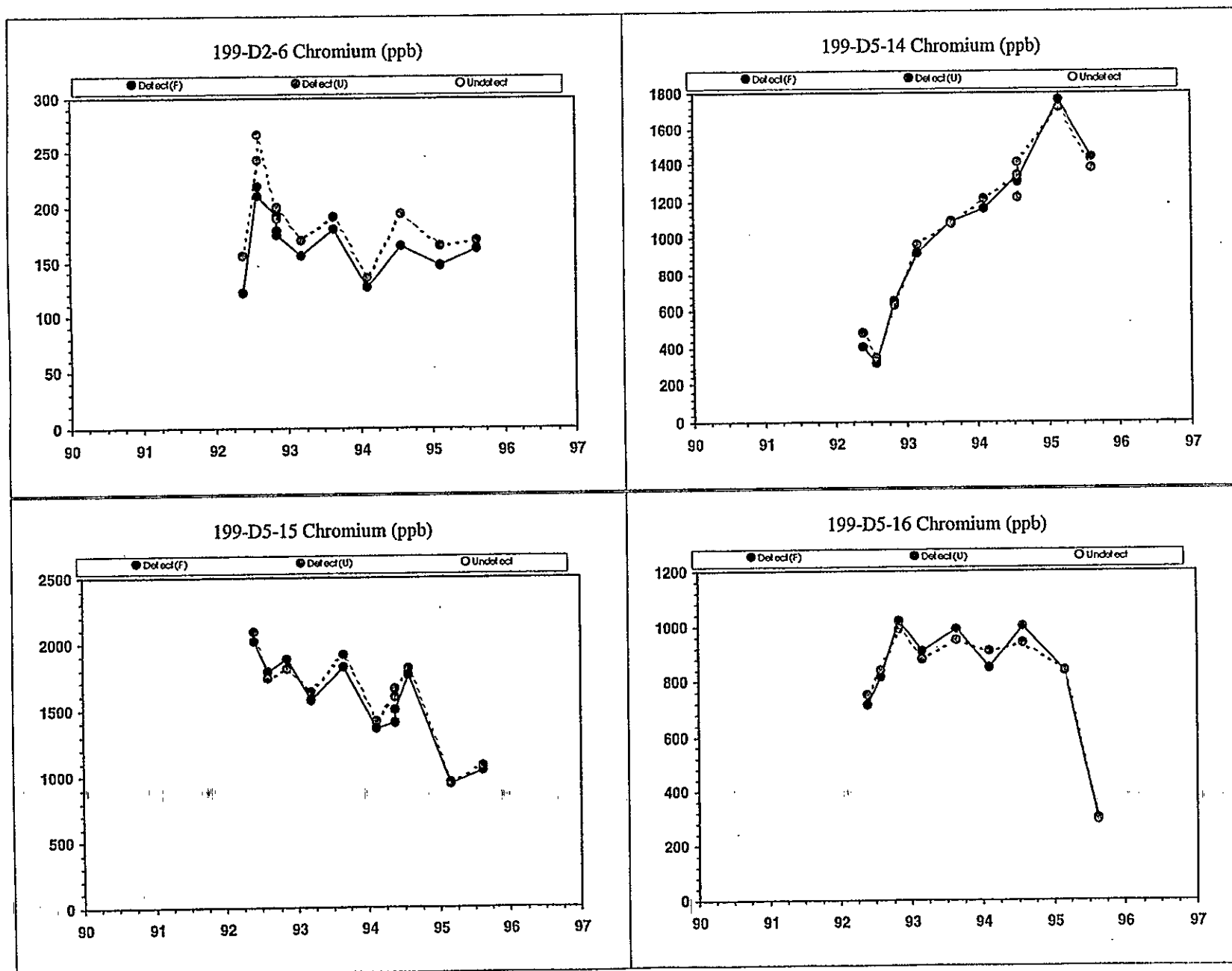


Figure 6-5. Chromium Trends in Selected 100-D/DR Area Inland Hot-Spot Wells

100-D Area Aquifer Sampling Tube Results (October / November, 1995)

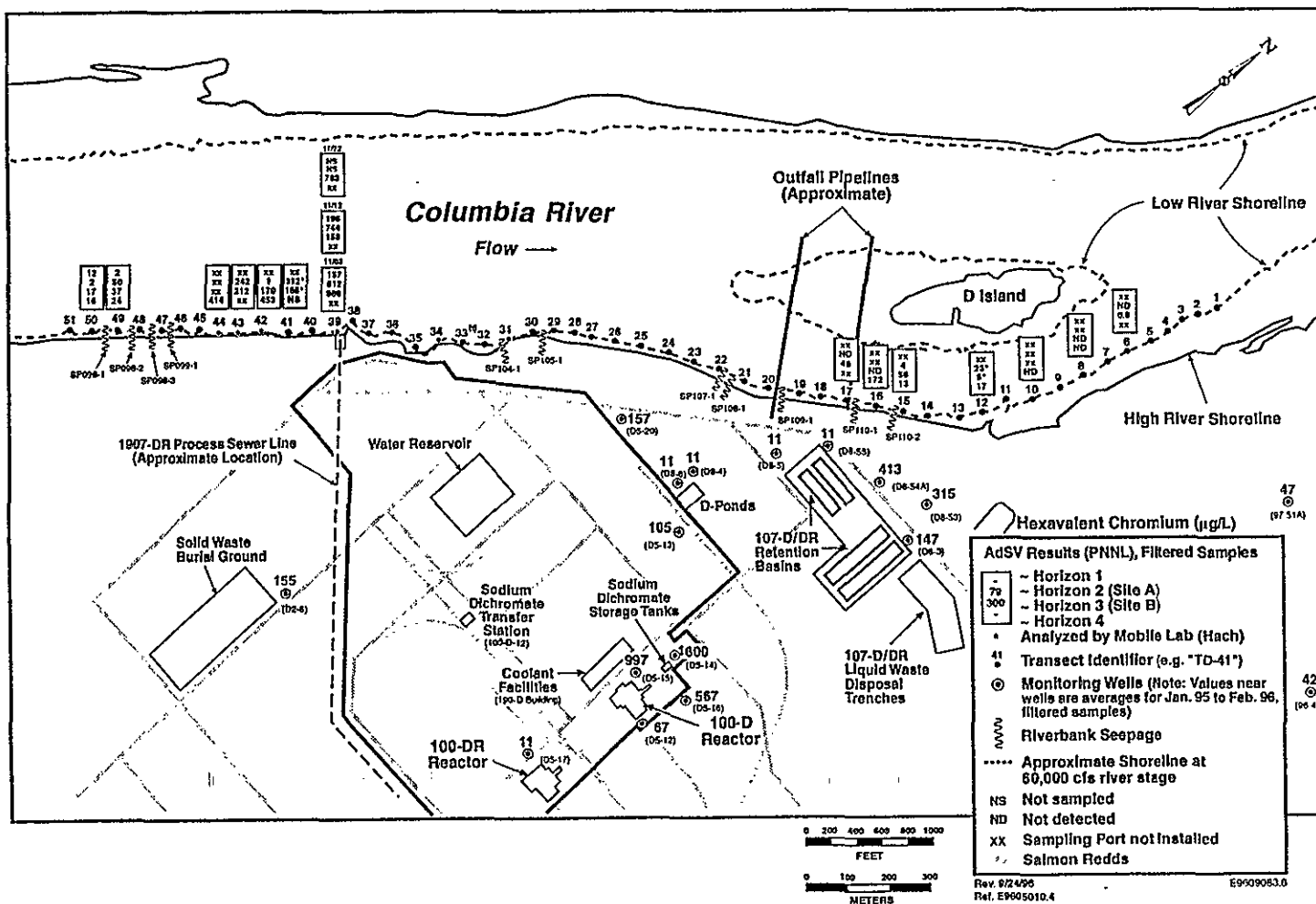


Figure 6-6. Chromium Along the Shoreline in the 100-D/DR Area (Hope and Peterson, 1996b)

100-D Area River Substrate Pore Water Results (October / November, 1995)

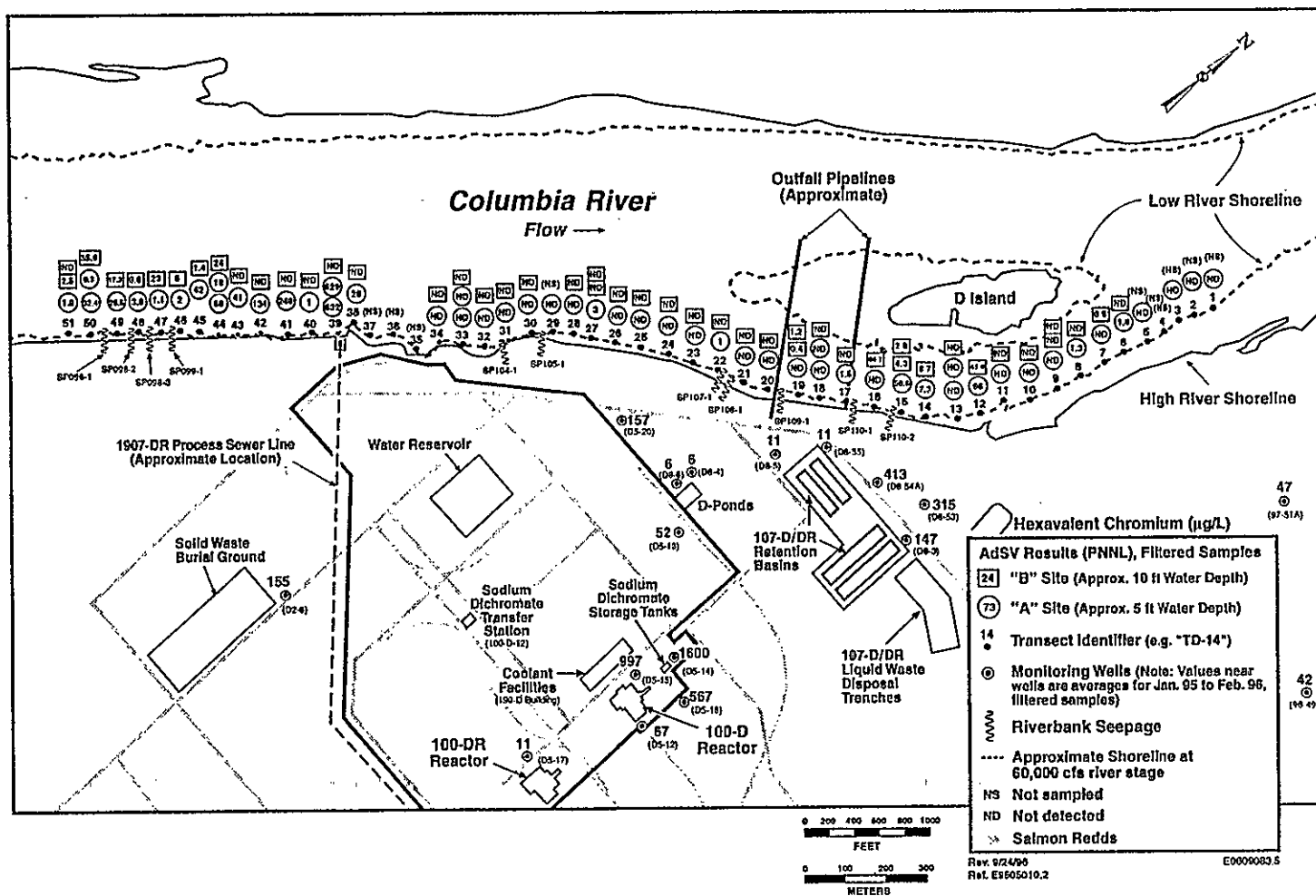


Figure 6-7. Chromium in River Substrate Pore Water in the 100-D/DR Area (Hope and Peterson 1996b)

Figure 6-8. Simulated Water Table Map for the 100-D/DR Area During 1955

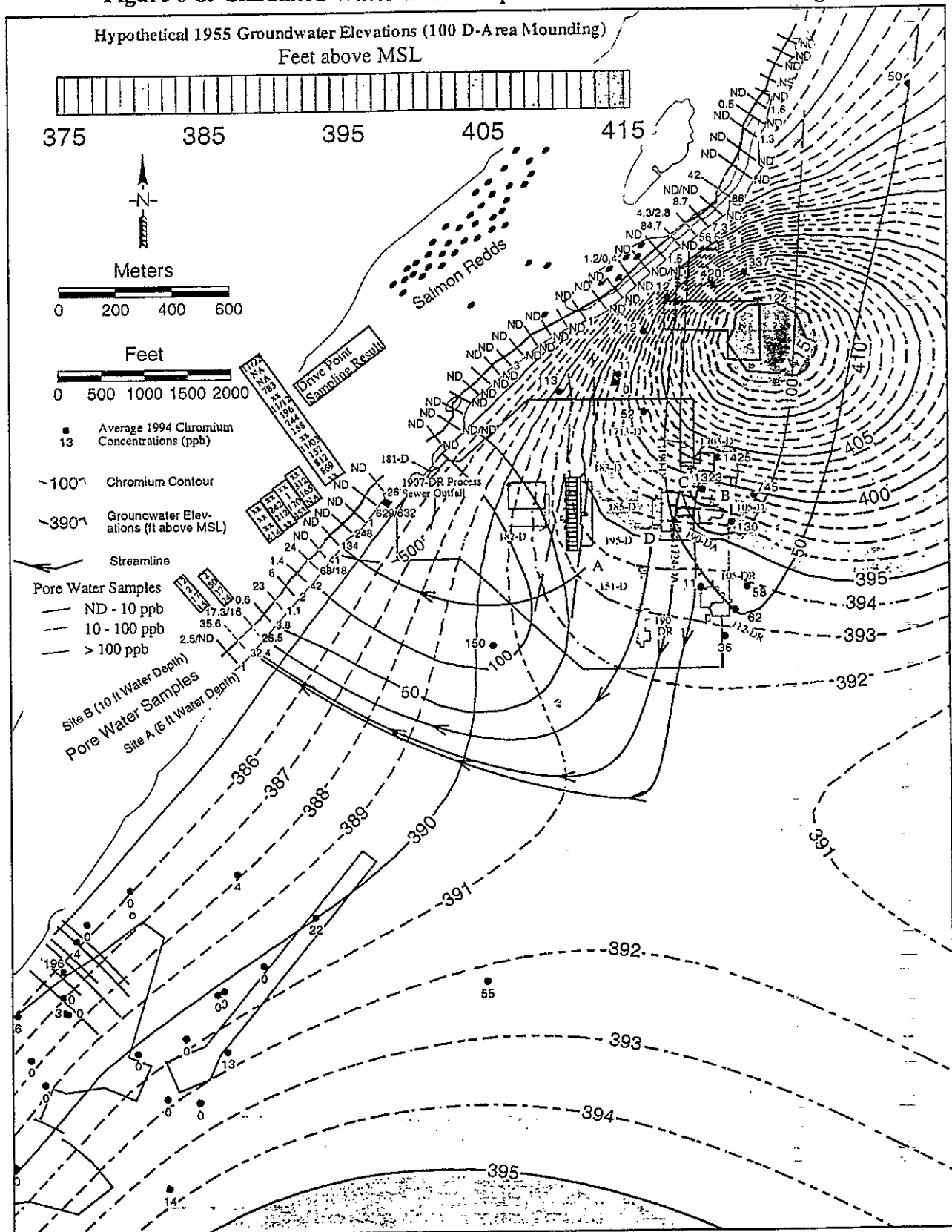


Figure 6-9. Strontium-90 Distribution in 100-D/DR Area

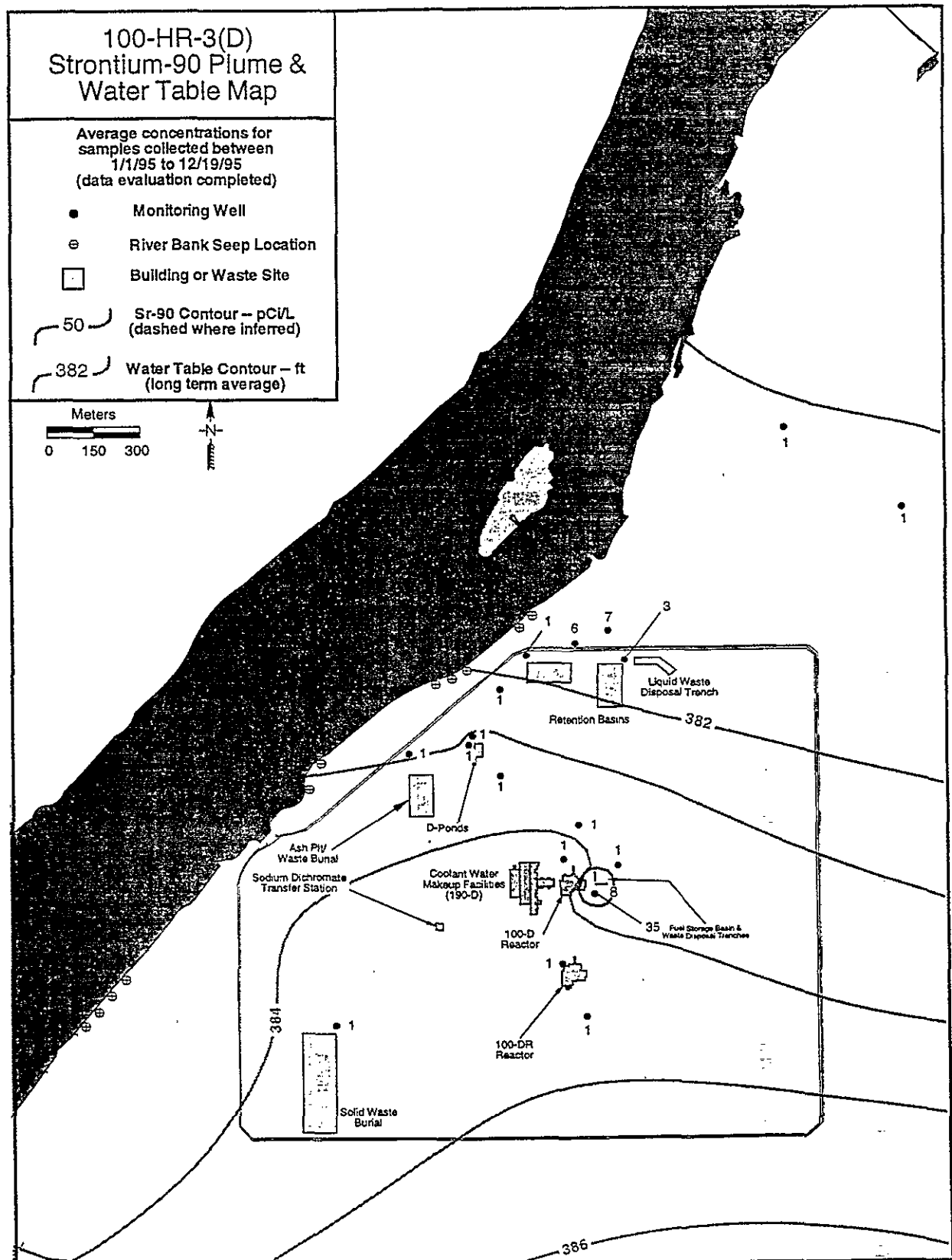
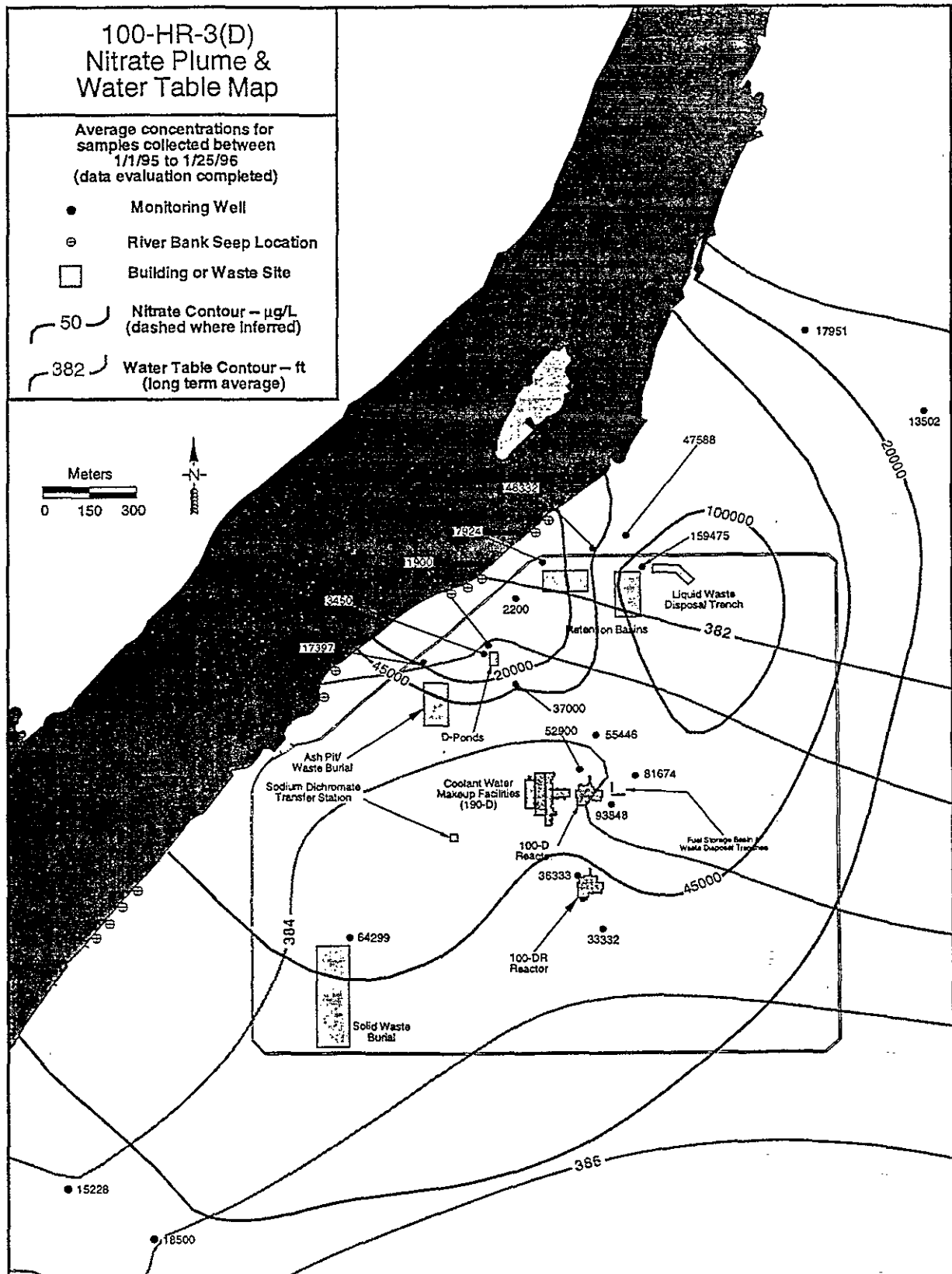


Figure 6-10. Nitrate Distribution in 100-D/DR Area



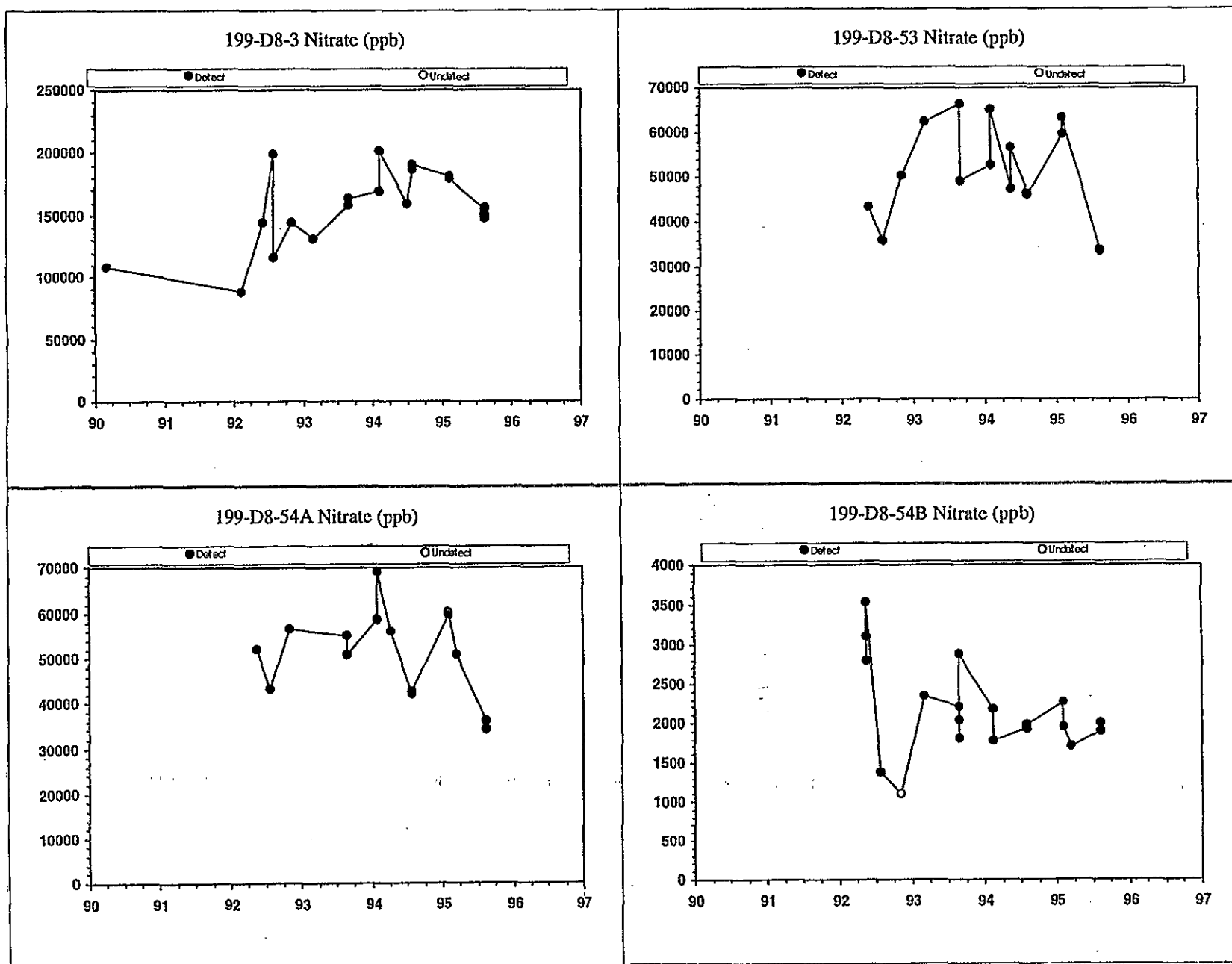
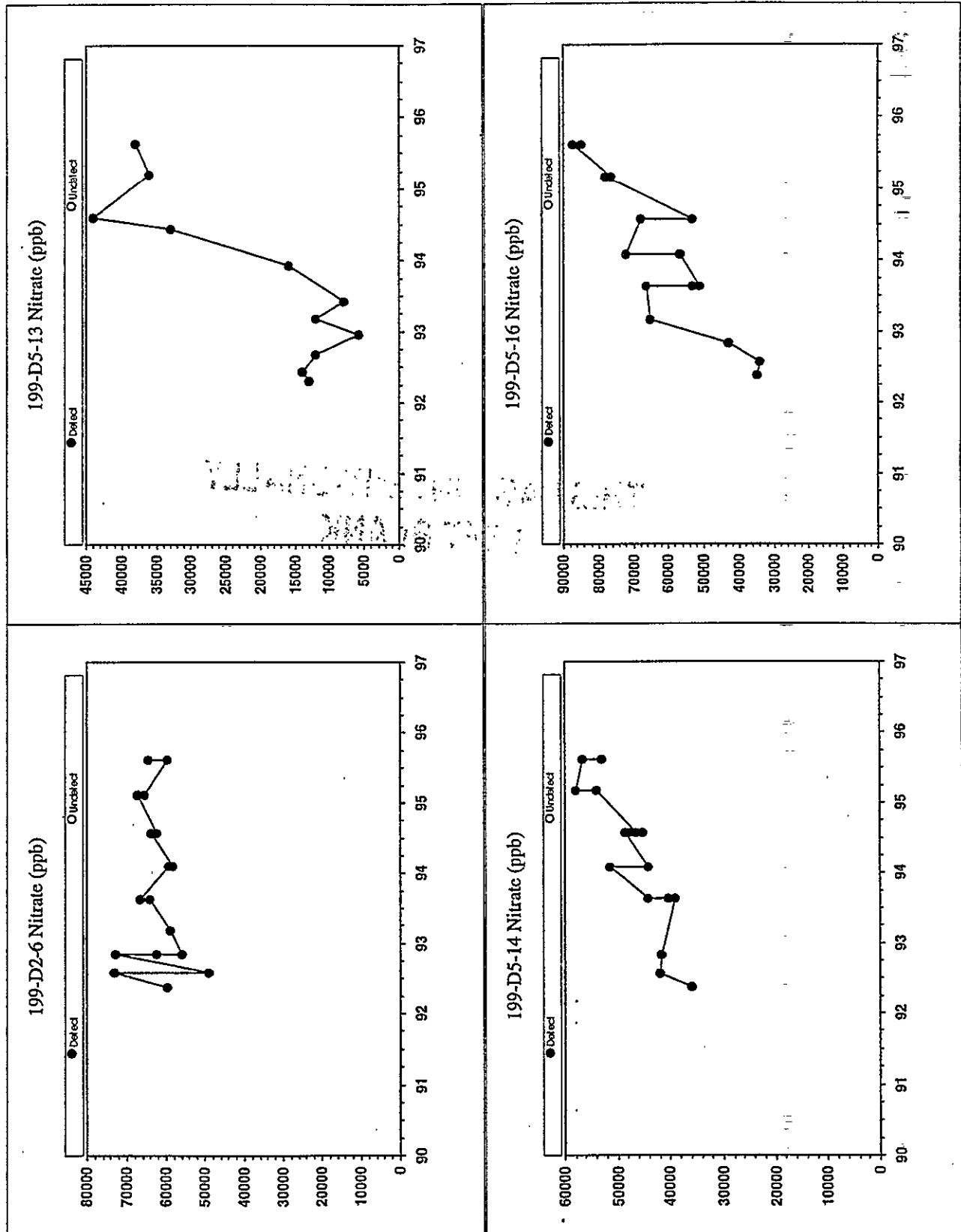


Figure 6-11. Nitrate Trends in Selected 100-D/DR IRM Network Wells

Figure 6-12. Nitrate Trends in Selected 100-D/DR Area Inland Hot-Spot Wells



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Figure 6-13. Cross Section (A-A') Perpendicular to 100-D/DR Area Shoreline

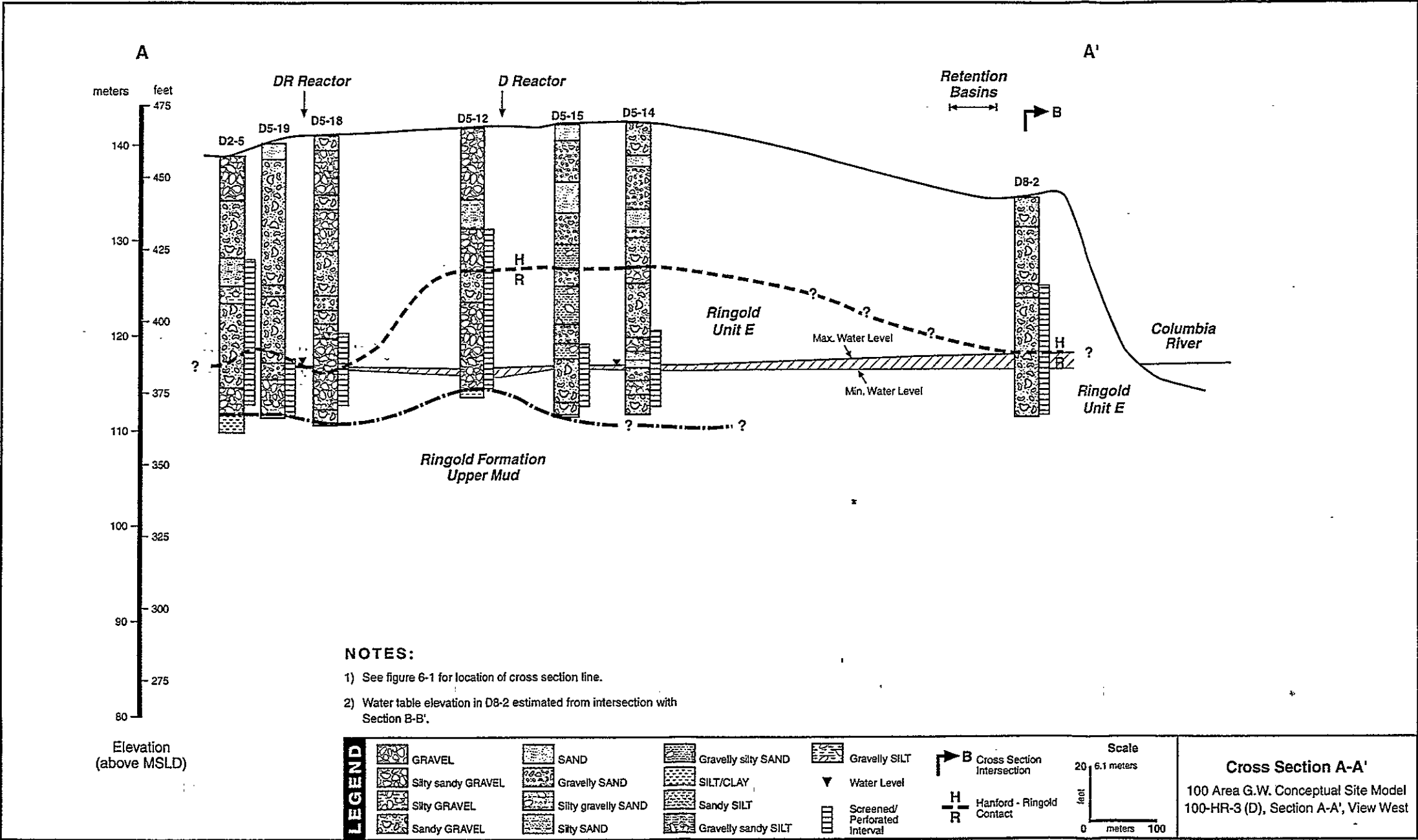


Figure 6-14. Cross Section (B-B') Parallel to 100-D/DR Area Shoreline

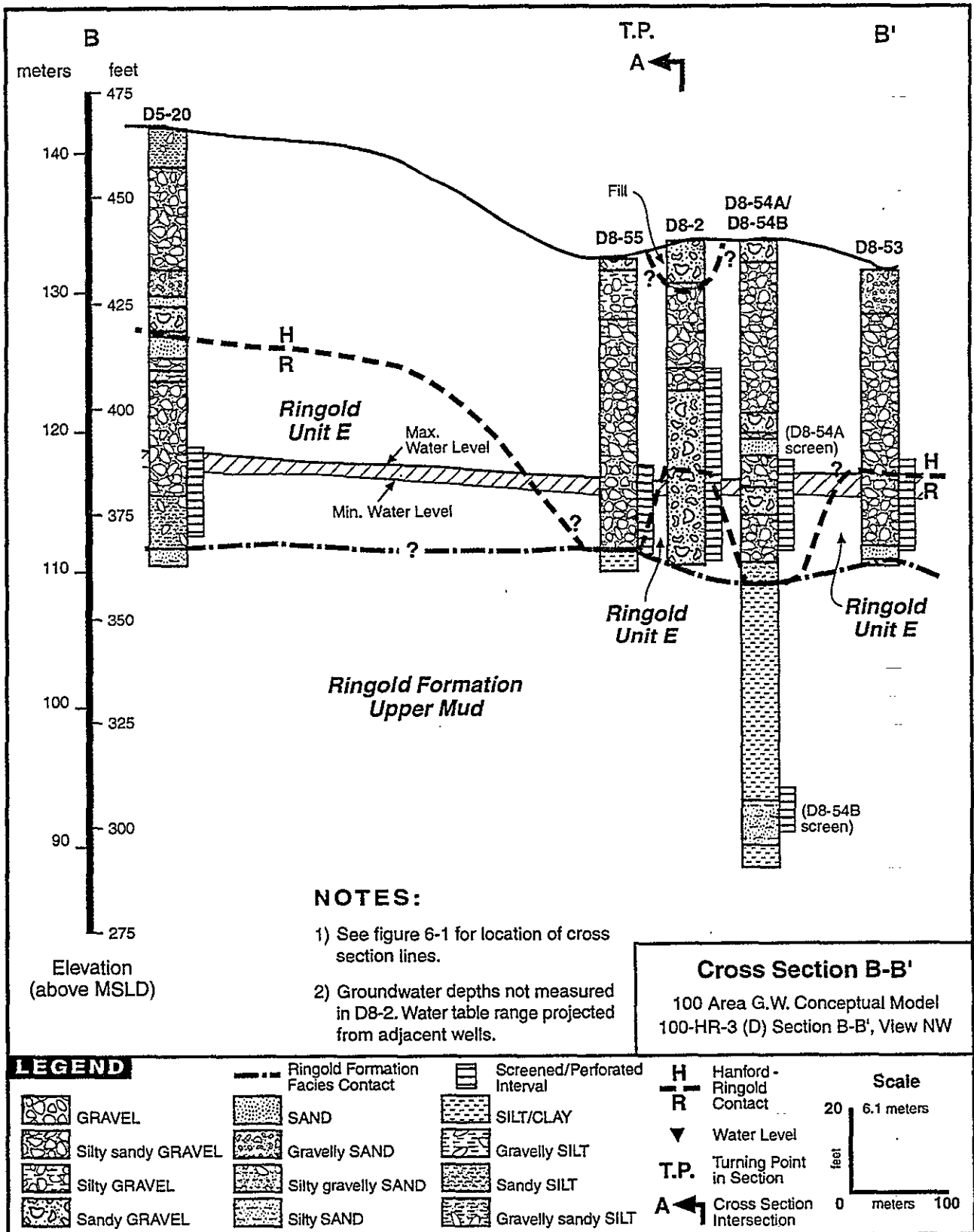
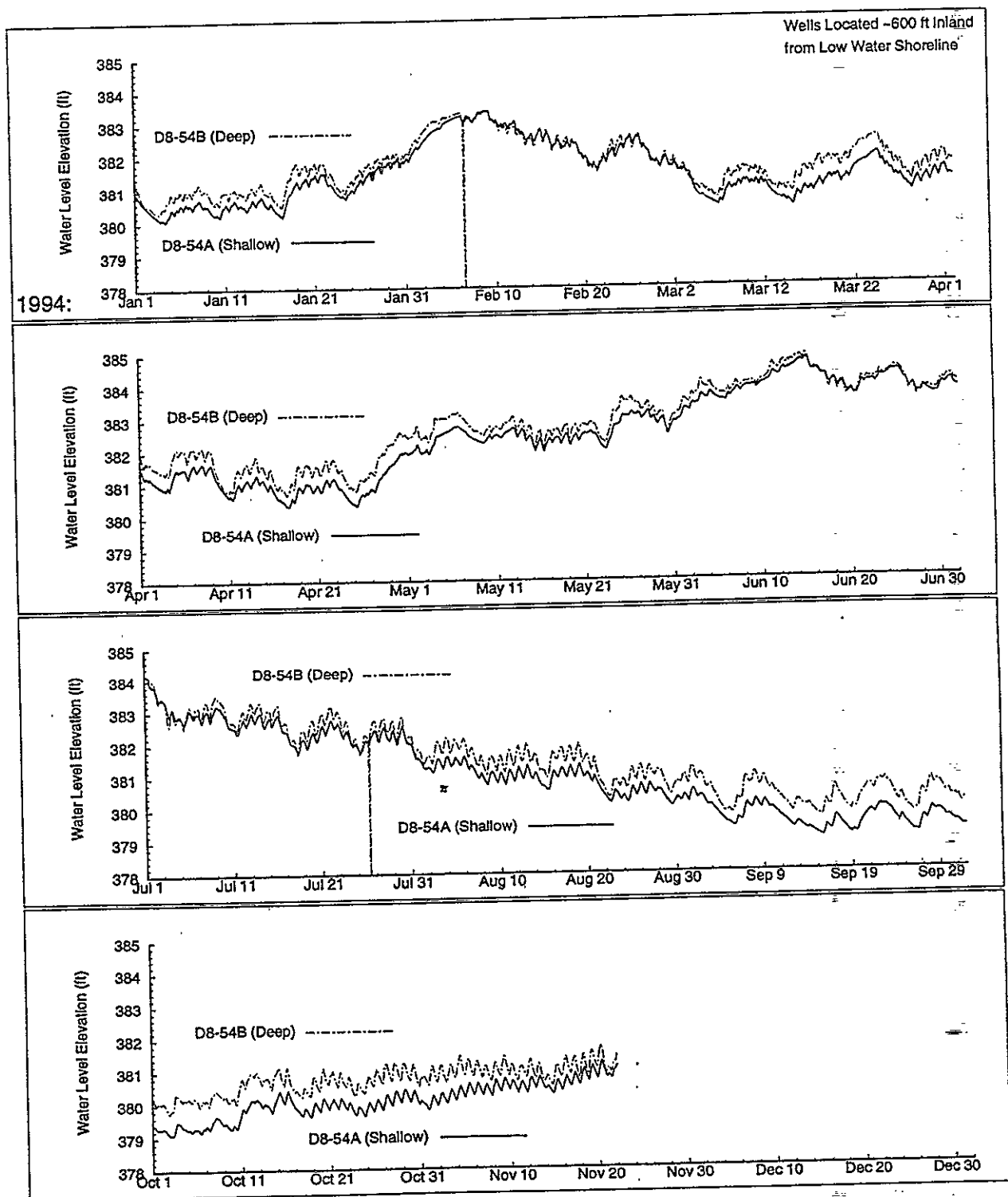


Figure 6-15. Hydrographs for Shallow and Deep Wells in the 100-D/DR Area



100-HR-3 (D/DR) Chemical Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Defects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Aluminum	ppb	N	21	72	23	27.40	323.00	95.13	50	SMCL	14	0	
Aluminum	ppb	Y	21	69	19	29.60	170.00	56.73	50	SMCL	4	4	6.86
Arsenic	ppb	N	2	2	1	5.00	5.00	5.00	50	MCL	0	0	
Arsenic	ppb	Y	2	2	1	3.70	3.70	3.70	50	MCL	0	0	8.06
Barium	ppb	N	21	72	71	13.80	338.00	79.92	1000	MCL	0	0	
Barium	ppb	Y	21	69	68	12.00	158.00	73.81	1000	MCL	0	0	91.57
Cadmium	ppb	N	21	72	0	0.00	0.00	0.00	10	MCL	0	0	
Cadmium	ppb	Y	21	69	5	1.00	2.90	1.90	10	MCL	0	0	3.07
Chloride	ppb	N	21	73	72	0.86	46900.00	13276.61	250000	SMCL	0	0	16863.99
Chromium	ppb	N	21	71	67	10.10	1720.00	214.55	50	MCL	39	0	
Chromium	ppb	Y	21	68	60	4.10	1760.00	184.23	50	MCL	26	11	16.61
Copper	ppb	N	21	72	22	3.60	126.00	17.80	1300	MCL-P	0	0	
Copper	ppb	Y	21	69	14	2.90	40.50	11.78	1300	MCL-P	0	0	0.85
Fluoride	ppb	N	21	37	34	150.00	770.00	317.35	1400	MCL	0	0	904.00
Iron	ppb	N	21	72	48	25.20	1080.00	286.46	300	SMCL	15	0	
Iron	ppb	Y	21	69	37	9.30	2210.00	181.12	300	SMCL	4	4	415.86
Lead	ppb	N	2	2	0	0.00	0.00	0.00	50	MCL	0	0	
Lead	ppb	Y	2	2	1	65.00	65.00	65.00	50	MCL	1	1	3.47
Manganese	ppb	N	21	72	48	1.10	150.00	17.02	50	SMCL	6	0	
Manganese	ppb	Y	21	69	34	0.91	94.50	15.65	50	SMCL	6	1	40.11
Mercury	ppb	Y	4	13	4	0.06	0.08	0.06	2	MCL	0	0	0.00
Nickel	ppb	N	21	72	18	10.50	62.00	31.53	100	MCL	0	0	
Nickel	ppb	Y	21	69	5	15.50	70.00	32.36	100	MCL	0	0	2.19
Nitrate	ppb	N	21	125	125	0.89	181056.12	38649.13	45000	MCL	43	9	31725.97
Phenol	ppb	N	4	9	0	0.00	0.00	0.00	2560	FEDWQ	0	0	
Selenium	ppb	N	2	2	0	0.00	0.00	0.00	10	MCL	0	0	
Selenium	ppb	Y	2	2	0	0.00	0.00	0.00	10	MCL	0	0	6.01
Silver	ppb	N	21	72	8	4.00	11.20	8.48	50	MCL	0	0	
Silver	ppb	Y	21	69	4	4.60	11.60	7.65	50	MCL	0	0	5.68
Sulfate	ppb	N	21	73	72	10.50	212000.00	67253.94	250000	SMCL	0	0	84676.12
Uranium	ppb	N	3	3	3	0.65	2.91	1.97	44	UMTR	0	0	9.28
Zinc	ppb	N	21	72	61	7.60	385.00	36.30	5000	SMCL	0	0	21.47
Zinc	ppb	Y	21	69	47	4.70	76.60	19.08	5000	SMCL	0	0	21.47

Table 6-1. Constituents Summary for 100-HR-3 (D) Operable Unit (Page 1 of 2)

100-HR-3 (D/DR) General Properties

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Dissolved Oxygen	mg/L	N	14	25	25	4.61	9.10	6.91			0	0	14935.41
pH Measurement	pH	N	18	130	130	6.35	10.78	8.29			0	0	8.07
Specific Conductance	umhos/cm	N	18	95	95	118.00	936.00	358.56			0	0	428.00
Temperature	Deg C	N	18	81	81	12.80	25.90	17.62			0	0	

100-HR-3 (D/DR) Radiological Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Carbon-14	pCi/L	N	17	19	11	3.31	22.80	8.36	2000	MCL	0	0	152.79
Gross Alpha	pCi/L	N	21	69	43	0.86	5.48	2.46	15	MCL	0	0	2.47
Gross Beta	pCi/L	N	21	69	63	2.48	84.20	11.51	50	MCL	3	1	7.44
Strontium-89/90	pCi/L	N	20	24	6	0.87	29.30	7.92			0	0	0.02
Strontium-90	pCi/L	N	21	46	13	0.00	38.70	8.71	8	MCL	2	1	0.02
Tritium	pCi/L	N	21	84	53	0.00	44000.00	8780.87	20000	MCL	6	3	162.00

Data Source: Hanford Environmental Information System. Abbreviations: MCL = EPA maximum contaminant level (primary); MCL-P = EPA maximum contaminant level (proposed); SMCL = EPA maximum contaminant level (secondary); EPA 440/5-86-001-USEPA Freshwater Chronic Water Quality Criteria; and UMTR = Uranium Mining Tailings Reclamation. "Background Values" are provisional 90th percentile values taken from Hanford Site Background: Part 3, Groundwater (DOE/RL-96-91, Decisional Draft)

Table 6-1. Constituents Summary for 100-HR-3 (D) Operable Unit (Page 2 of 2)

Table 6-2. Constituents in 100-D/DR Area Wells that Exceed Standards (Page 1 of 2)

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Aluminum (50 $\mu\text{g/L}$)	199-D5-13 199-D8-4 199-D8-5 199-D8-6	93 170 83 170	1,300 760 500 860	Possible source is water treatment plant filter backwash. Alum was used extensively as a flocculant.
Chromium (50 $\mu\text{g/L}$)	199-D2-6 199-D5-12 199-D5-13 199-D5-14 199-D5-15 199-D5-16 199-D5-20 199-D8-3 199-D8-53 199-D8-54A 699-97-51A	232 90 190 1,760 1,050 831 73 232 359 479 50	2,100 2,940 1,300 2,200 2,410 2,790 600 1,090 700 600 1,650	Widespread from multiple sources, including reactor coolant effluent mounds that were created beneath leaking retention basins; disposal of chromium-laden decontamination solutions; and leakage/spillage of sodium dichromate stock materials.
Gross Beta (50 pCi/L)	199-D5-12	84	2,940	Reflects strontium-90, whose source is probably fuel storage basin effluent disposal to trenches near the 105-D reactor building.
Iron (300 $\mu\text{g/L}$)	199-D5-12 199-D5-14 199-D5-15 199-D5-16	370 2,210 1,200 1,700	2,940 2,200 2,410 2,790	Common in natural Hanford sediments. Possible association with carbon-steel well casing.
Lead (50 $\mu\text{g/L}$)	199-D8-3	65	1,090	Isolated occurrence (although lead arsenate was commonly used as a pesticide in pre-Hanford orchards)
Manganese (50 $\mu\text{g/L}$)	199-D8-54B	95	600	Common in natural Hanford sediments.
Nitrate (45,000 $\mu\text{g/L}$)	199-D2-6 199-D5-12 199-D5-13 199-D5-14 199-D5-15 199-D5-16 199-D8-3 199-D8-53 199-D8-54A	77,469 95,618 49,000 63,303 58,433 87,207 181,056 63,303 60,204	2,100 2,940 1,300 2,200 2,410 2,790 1,090 700 600	Widespread, multiple sources--including nitric acid decontamination solutions.
Strontium-90 (8 pCi/L)	199-D5-12	39	2,940	Probable source is fuel storage basin effluent disposal to trenches near the 105-D reactor building

Table 6-2. Constituents in 100-D/DR Area Wells that Exceed Standards (Page 2 of 2)

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Tritium (20,000 pCi/L)	199-D5-12	44,000	2,940	Common in fuel storage basin effluent.
	199-D5-16	24,600	2,790	
	199-D5-17	26,400	3,360	

Table 6-3. 100-DR-1 Source Operable Unit High-Priority Waste Sites

Waste Site	Physical Description of Waste Site	Former Waste Site Use	¹ Contaminants of Potential Concern
116-D-7 Retention Basin	Reinforced rectangular concrete retention basin; two cells, 142.3 m long x 70.1 m wide x 7.3 m deep.	Held cooling water effluent from 105-D and 105-DR Reactors for cooling/decay before release to the Columbia River; probably received ruptured fuel element waste.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, chromium, Ni-63, Th-228, U-238
116-DR-9 Retention Basin	Reinforced rectangular concrete retention basin; two cells, 182.9 m long x 83.2 m wide x 6.1 m deep.	Held cooling water effluent from 105-D and 105-DR Reactors for cooling/decay before release to the Columbia River; probably received ruptured fuel element waste.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-239, Sr-90, arsenic, chromium, PCBs, benzo(a)pyrene, Ra-226, U-238
116-DR-1, 116-DR-2 Process Effluent Trenches	Unlined co-located trenches. Length and width varies, depth 6.1 m deep.	Received effluent overflow from the 116-D-7 and 116-DR-9 Retention Basins at times of high activity caused by fuel element failure.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-239, Na-22, chromium
107-D and 107-DR Sludge Trenches (includes 5 separate trenches)	Unlined trenches. Trench #1, #2 and #3 are each 32.0 m long x 9.1 m wide x 3.1 m deep. Trench #4 - 25.9 m x 6.1 m x 3.1 m deep. Trench #5 - 15.2 m x 6.1 m x 3.1 m deep.	Received sludge from 116-D-7 and 116-DR-9 Retention Basins; sludge dredged from basins, disposed to soil then trench backfilled.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-238, Pu-239/240, Sr-90, arsenic, chromium, PCBs, benzo(a)pyrene
116-D-1A and 116-D-1B Fuel Storage Basin Trenches	116-D-1A, unlined trench, 39.6 m long x 3.1 m wide x 1.8 m deep. 116-D-1B, unlined trench, 30.5 m wide x 3.1 m wide x 4.6 m deep.	Received contaminated water from 105-D Fuel Storage Basin.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-239/240, Na-22, Ra-226, Sr-90, Th-228, chromium
² 100-D and 100-DR Buried Process Effluent Pipelines	Buried parallel buried process effluent pipelines. Total length approximately 2,100 m pipe diameter 152 cm buried up to 6 m below surface.	Transported reactor cooling water from the 105-D and 105-DR Reactors to the 116-D-7 and 116-DR-9 Retention Basins, outfall structures and the 116-DR-1 and 116-DR-2 Trenches. The buried process effluent pipelines may contain contaminated sludge and scale.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-238, Pu-239/240, Sr-90, U-238
³ 116-D-2A Crib	Unlined earthen structure, 3.1 m x 3.1 m x 3.1 m deep.	Received liquid effluents following fuel cladding failures from 105-D Reactor.	Cs-137, Co-60, Eu-152, Eu-154, Ra-226, Sr-90, Th-228
116-D-9 Crib	Unlined earthen structure, 3.1 m x 3.1 m x 3.1 m deep.	Received liquid effluent from seal pits in the 117-D exhaust air filter building.	Th-228, arsenic, chromium

Cs-137	=	¹³⁷ cesium
Co-60	=	⁶⁰ cobalt
Eu-152	=	¹⁵² europium
Eu-154	=	¹⁵⁴ europium
Eu-155	=	¹⁵⁵ europium
Na-22	=	²² sodium
Ni-63	=	⁶³ nickel
Pu-238	=	²³⁸ plutonium
Pu-239/240	=	^{239/240} plutonium
Ra-226	=	²²⁶ radium
Sr-90	=	⁹⁰ strontium
Th-228	=	²²⁸ thorium

¹ The contaminants of potential concern were identified from the Qualitative Risk Assessment.

² Contaminants are based on analogous site 100-H Buried Process Effluent Pipeline.

³ Contaminants were identified in soil below 15 ft, and there is little likelihood of exposure to humans and ecological receptors.

Table 6-4. 100-DR-2 Source Operable Unit High-Priority Waste Sites

Waste Site	Physical Description of Waste Site	Former Waste Site Use	Contaminants of Potential Concern ¹
116-DR-3 Storage Basin Trench	Unlined trench 18 m x 12 m x 3.1 m deep.	Received 4 million liters of contaminated sludge and water removed from the 105-DR Fuel Storage Basin during 1955.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, K-40, Pu-239/240, Ra-226, Ra-228, Sr-90, Th-228
116-DR-4 Liquid Disposal Trench	Unlined trench 3.1 m x 3.1 m x 3.1 m deep.	Received 4 thousand liters of reactor cooling water isolated from tubes containing ruptured fuel elements.	Cs-137, Co-60, Eu-152, Sr-90
116-DR-6 Liquid Disposal Trench	Unlined trench 15.2 m x 3.1 m x 3.1 m deep.	Received reactor cooling water during effluent system maintenance and Ball 3X upgrade.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Na-22, Ni-63, Pu-239/240, Chromium.
Sodium Dichromate/Acid Pumping Station	Site of repeated spillage and discharge of contaminated liquids. Contaminated volume is a 12.2 m dia. circle 6.1 m deep including a French drain.	Received unknown volumes of undiluted sodium dichromate and acid solutions from flushing and draining of hoses and lines used to off-load rail cars and tank cars.	Cs-137, Eu-152, K-40, Ra-226, Ra-228, Th-228, Chromium
118-D-1 Burial Ground	A series of unlined trenches in an area 137.2 m x 114.3 m x 6.1 m deep.	Received irradiated reactor equipment and other radioactive and nonradioactive solid waste.	Co-60
118-D-2 Burial Ground	A series of unlined trenches and pits in an area 304.8 m x 108.8 m x 6.1 m deep.	Received irradiated reactor equipment and other radioactive and nonradioactive solid waste.	Cs-137, Co-60, Eu-154
118-D-3 Burial Ground	A series of unlined trenches in an area 304.8 m x 76.2 m x 6.1 m deep.	Received reactor parts and other radioactive and nonradioactive solid waste. Site also contained a burning pit.	Cs-137, Co-60, Eu-154
118-D-4 Construction Burial Ground	A series of unlined trenches in an area 182.8 m x 61.0 m x 6.1 m deep.	Received irradiated reactor components and hardware during 105-D Reactor modifications.	Co-60
118-D-5 Ball 3X Burial Ground	Two parallel burial trenches each 12.2 m x 12.2 m x 3.1 m deep.	Received irradiated equipment from 105-DR Reactor.	Co-60
118-DR-1 Gas Loop Burial Ground	Gunnite-lined trench 38.1 m x 22.8 m x 4.6 m deep.	Received irradiated metal assemblies from the 105-DR Reactor gas loop.	Co-60
128-D-1 Burning Pit	Unlined trench in an area 30.5 m x 30.5 m x 3.1 m deep.	Received nonradioactive combustible materials including paint waste, office waste, and chemical solvents.	None identified
Buried VSR Thimble Site 4C	Unlined trench in an area 20.5 m x 7.8 m x 3.1 m deep.	Received irradiated vertical safety rod (VSR) thimbles.	Co-60
Buried VSR Thimble Site 4D	Unlined trench in an area 42.9 m x 17.1 m x 6.1 m deep.	Received irradiated vertical safety rod thimbles.	Co-60
Minor Construction Burial Ground #1	Unlined trench in an area 30.5 m x 15.2 m x 6.1 m deep.	Received reactor equipment and other radioactive and nonradioactive solid waste.	Co-60
Minor Construction Burial Ground #4	Two unlined trenches in an area 30.5 m x 15.2 m x 6.1 m deep.	Received reactor equipment and other radioactive and nonradioactive solid waste.	Co-60
Minor Construction Burial Ground #6	Unlined trench in an area 15.2 m x 15.2 m x 6.1 m deep.	Received reactor equipment and other radioactive and nonradioactive solid waste.	Co-60

Cs-134 = ¹³⁴cesium
 Cs-137 = ¹³⁷cesium
 Co-60 = ⁶⁰cobalt
 Eu-152 = ¹⁵²europium
 Eu-154 = ¹⁵⁴europium
 Eu-155 = ¹⁵⁵europium
 K-40 = ⁴⁰potassium

Na-22 = ²²sodium
 Ni-63 = ⁶³nickel
 Pu-239/240 = ^{239/240}plutonium
 Ra-226 = ²²⁶radium
 Ra-228 = ²²⁸radium
 Sr-90 = ⁹⁰strontium
 Th-228 = ²²⁸thorium

¹ The contaminants of potential concern were identified from the Qualitative Risk Assessment (QRA).

Table 6-5. Known Facility Sources for Chromium in the 100-D/DR Area (Page 1 of 2)

Waste Site Number	Facility Name	Operating Period	Liquid Effluent Summary
116-D-1A	105-D Storage Basin Trench #1	1947-52	200,000 liters of contaminated water from fuel storage basin; 1,000 kg of sodium dichromate
116-D-1B	105-D Storage Basin Trench #2	1953-67	8 million liters of liquid waste; fuel storage basin water and decontamination solutions; 700 kg sodium dichromate
116-D-2	105-D Pluto Cribs	1950-52	4,000 liters of liquid wastes; 0.004 kg sodium dichromate
116-D-5	1904-D Outfall Structure	1944-75	Reactor coolant and process sewer effluent; possible leakage and release to shoreline via concrete spillway
116-D-7	107-D Retention Basin	1944-67	Temporary storage of reactor coolant, prior to discharge into river; significant leakage created mound on underlying water table
116-DR-1	107-DR Liquid Waste Disposal Trench #1 (used for infiltration test in 1967)	1950-67	40 million liters of highly contaminated reactor coolant from fuel element ruptures; 40 kg sodium dichromate
116-DR-2	107-DR Liquid Waste Disposal Trench #2	1952-67	Received overflow from Trench #1; 40 kg sodium dichromate
116-DR-5	1904-DR Outfall Structure	1956-65	Reactor coolant; possible leakage and release to shoreline via concrete spillway
116-DR-9	107-DR Retention Basin	1950-65	Temporary storage of coolant, prior to discharge into river; possible significant leakage contributing to groundwater mound
126-D-2	184-D Coal Pit	1970s-86	Original coal pit subsequently used as burial ground; possible sodium dichromate crystals
(Unlisted)	1907-DR Outfall Structure	1950-65	Received effluent via 105-DR process sewer lines; contained overflow from coolant storage basins and other process wastes possibly containing chromium
(Unlisted)	Sodium dichromate storage tanks near 108-D building (north of 105-D reactor)		Leakage of sodium dichromate stock solution from tanks and supply pipelines to 190-D building
(Unlisted)	100-D-12 Transfer Station; sodium dichromate unloading and transfer; northwest of 105-DR reactor		Leakage of sodium dichromate stock solution during transfer from railcars and from associated piping

Table 6-5. Known Facility Sources for Chromium in the 100-D/DR Area (Page 2 of 2)

Waste Site Number	Facility Name	Operating Period	Liquid Effluent Summary
(Unlisted)	"Sodium" trench associated with 190-D building		Leakage/spillage of sodium dichromate stock solution at point of introduction to unused coolant

Sources: Listed waste sites -- *100-D Technical Baseline Report*, WHC-SD-TI-181, Rev. 0, August 1993 (Carpenter 1993); unlisted sites, project information described in internal technical memorandum (Connelly 1996)

Table 6-6. Hydrologic Units Monitored by 100-D/DR Area Wells

Well	Screened Interval Elevation; meters/(ft)	Hydrogeologic Unit	Average Ground- water Elevation meters/(ft)
D8-54A	118.2 - 117.8 m (387.7 - 366.6 ft)	Hanford formation	116.3 m/ (381.6 ft)
D8-54B	94.3-91.1 m (309.3 - 298.7 ft)	Ringold Formation upper mud	116.5 m/(382.2 ft)

Notes:

1. Groundwater elevations averaged from quarterly steel tape measurements conducted from 1-1-94 to 8-30-95.
2. Screened intervals from unpublished Westinghouse Hanford Company geologic well summaries.
3. Survey elevations from ICF Kaiser Hanford, 1992.

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μS/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
Wells representative of conditions at or near the water table:											
699-101-48B	320	379.67	5.4	377.4	382.8	6					
199-D8-55	390	381.59	5.1	379.1	384.1	20	271	105	226	331	3
199-D8-5	500	382.30	3.9	380.5	384.4	25	215	26	201	227	11
199-D5-20	600	382.94	3.4	381.3	384.7	21	393	73	355	428	4
199-D8-54A	600	381.58	5.0	379.1	384.1	25	591	190	457	647	6
199-D8-53	700	381.55	5.0	379.0	384.0	22	555	115	494	609	4
199-D8-4	760	383.07	3.2	381.4	384.6	26	133	37	113	150	9
199-D8-6	860	383.02	3.6	381.5	385.1	22	142	27	133	160	12
199-D8-3	1,090	381.46	4.1	379.5	383.6	21	727	191	654	845	6
199-D5-13	1,300	383.32	2.0	382.3	384.3	26	492	190	380	570	29
699-97-51A	1,650	381.09	2.0	380.2	382.2	21	412	19	404	423	4
199-D2-6	2,100	384.20	2.1	383.2	385.4	22	608	193	543	736	4
199-D5-14	2,200	383.88	0.7	383.6	384.3	8	567	270	432	702	2
199-D5-15	2,410	384.17	0.9	383.9	384.7	8	553	154	494	648	4
699-97-43	2,660	378.38	0.5	378.2	378.7	11	378	22	365	387	4
199-D5-16	2,790	383.80	0.6	383.6	384.2	8	552	72	516	588	2
199-D5-12	2,940	383.79	2.8	381.6	384.5	21	874	121	815	936	4
699-96-49	3,080	381.40	5.3	379.3	384.5	22	383	134	298	432	4
199-D5-17	3,360	384.49	0.9	384.1	385.0	18	450	213	379	592	5
199-D5-18	3,670	384.32	0.6	384.1	384.7	8	665	76	635	711	3
199-D5-19	3,800	384.63	0.5	384.5	385.0	8	678	103	626	729	2
199-D2-5	3,950	384.70	0.8	384.3	385.1	20	534	62	514	576	4

Table 6-7. Water Level and Specific Conductance in 100-D/DR Area Wells (Page 1 of 2)

Table 6-7. Water Level and Specific Conductance in 100-D/DR Area Wells (Page 2 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μ S/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
699-96-43	3,990	378.83	0.4	378.7	379.1	14	389	59	361	420	7
<i>Wells with open intervals significantly below the water table:</i>											
199-D8-54B	600	382.22	7.8	379.8	387.6	25	457	62	413	475	5
Notes: Wells are listed in order of increasing distance from the river shoreline, as defined by low river stage. Data are representative of conditions between January 1, 1994 and August 30, 1995. Data source: HEIS.											

Table 6-8. Aquifer Test and Drawdown Test Results for 100-D/DR Area Wells

Well Number	Sediment Description		Screened Formation	Slug Test K (ft/d) cm/sec	Drawdown Test K (ft/d) cm/sec
	Field Log	Sieve Analysis			
199-D-2	Sandy gravel	Gravelly sand	Ringold Unit E	(40) 0.0141	
199-D5-14	Sandy gravel/gravelly sand	Sand	Ringold Unit E	(30) 0.0106	(49) 0.0173
199-D5-15	Sandy gravel	Gravel/sand	Ringold Unit E	(30) 0.0035	(54) 0.0190
199-D5-16	Clayey sandy gravel/sandy gravel	Sandy gravel	Ringold Unit E	(10) 0.0035	(13) 0.0046
199-D5-17	Sandy gravel/clayey sandy gravel	Gravelly sand	Ringold Unit E	(10) 0.0035	(16) 0.0056
199-D5-18	Sandy gravel	Sandy gravel	Ringold Unit E	(60) 0.021	(84) 0.0296
199-D5-19	Gravelly sand/clayey sandy gravel	Sand/gravel	Ringold Unit E	(40) 0.0141	(56) 0.0198
199-D5-20	Silty sandy gravel	Sand	Hanford	(40) 0.0141	
199-D8-53	Silty sandy gravel	Sandy gravel	Ringold Unit E	(530) 0.187	
199-D8-54A	Silty sandy gravel	Slightly gravelly sand	Hanford	(400) 0.141	
199-D8-55	Sandy silty gravel	Gravel/sand	Hanford	(20) 0.007	
699-93-48	Sandy gravel	Sandy gravel	Hanford	(60) 0.0211	
699-91-46	Sandy gravel/gravelly sand	Sand	Hanford	(790) 0.2787	

cm/sec = centimeters per second

ft/d = feet per day

K = hydraulic conductivity

NA = not available

Sources: Drawdown test data from DOE-RL (1995j). Slug test data from DOE-RL (1994c)

Table 6-9. Physical Properties for Aquifer Sediments in the 100-D/DR Area (Page 1 of 2)

Well Number/ Depth Interval (m [ft])	Designation	Sediment Description, Formation	Specific Gravity (g/cm ³)	Bulk Density (g/cm ³)	Porosity (%)	K _v Saturated (cm/sec)
D5-14 9.76 to 10.37 m (32 to 34 ft)	vadose	Slightly gravelly SAND, Hanford formation	NA	NA	NA	3.1E-03
D5-14 18.75 to 19.05 m (61.5 to 62.5 ft)	vadose	Silty sandy GRAVEL, Ringold Formation Unit E	2.24	2.15	21.41	2.7 E-04
D5-14 30.49 to 30.70 m (100 to 101 ft)	aquitard	Silty sandy GRAVEL, Ringold F Unit E	2.70	2.13	21.10	7.5 E-05
D8-55 22.10 to 22.41 m (72.5 to 73.5 ft)	aquitard	Sandy SILT, Ringold Formation Upper Mud	2.50	1.36	45.70	6.8 E-07
D5-17 11.13 to 11.43 m (36.5 to 37.5 ft)	vadose	Silty sandy GRAVEL, Hanford formation	2.69	2.06	23.26	1.6 E-02
D5-17 20.12 to 20.58 m (66 to 67.5 ft)	vadose	Sandy GRAVEL, Hanford formation	2.80	2.03	27.65	4.3 E-03
D5-17 29.88 to 30.18 m (98 to 99 ft)	aquifer	Sandy GRAVEL, Ringold Formation Unit E	2.68	2.42	9.48	3.1 E-03
D5-17 31.71 to 31.86 m (104 to 104.5 ft)	aquitard	SILT, Ringold Formation Upper Mud	NA	NA	NA	2.0 E-06
D8-54B 9.15 to 9.30 m (30 to 30.5 ft)	vadose	Silty Sandy GRAVEL, Hanford formation	NA	NA	NA	1.4 E-02
D8-54B 17.68 to 17.84 m (58 to 58.5 ft)	aquifer	Silty sandy GRAVEL, Hanford formation	NA	NA	NA	Not measured
D8-54B 18.60 to 18.75 m (61 to 61.5 ft)	aquifer	Sandy GRAVEL, Hanford formation	2.70	1.95	27.63	4.2 E-04
D8-54B 23.48 to 23.78 m (77 to 78 ft)	aquitard	Sandy SILT, Ringold Formation Upper Mud	2.64	1.54	41.51	1.2 E-04

Table 6-9. Physical Properties for Aquifer Sediments in the 100-D/DR Area (Page 2 of 2)

Well Number/ Depth Interval (m [ft])	Designation	Sediment Description, Formation	Specific Gravity (g/cm ³)	Bulk Density (g/cm ³)	Porosity (%)	K _v Saturated (cm/sec)
D8-54A 14.94 to 15.55 m (49 to 51 ft)	vadose	Silty sandy GRAVEL, Hanford formation	2.69	2.15	NA	1.1 E-04
D8-53 20.85 to 21.00 m (68.4 to 68.9 ft)	aquitard	Silty Sand, Ringold Formation Upper Mud	NA	NA	NA	2.1 E-07

NOTE: Data from unpublished Westinghouse Hanford Company Geotechnical Engineering Laboratory data packages.

cm/sec = centimeters per second
 ft = feet
 g/cm³ = grams per cubic centimeter
 K_v = vertical hydraulic conductivity
 m = meters
 NA = not available

7.0 100-HR-3 OPERABLE UNIT: 100-H AREA

The 100-HR-3 (H) Operable Unit Contains the groundwater underlying the 100-H Area. It also includes adjacent areas where contaminated groundwater from the 100-H Area may pose a risk to human and ecological receptors. Examples of adjacent areas are the riverbed, where groundwater may upwell into sediments that form habitat for aquatic life, and locations where water seeps from the riverbank during low river conditions. Figure 7-1 is an index map for the 100-H Area that shows the locations of groundwater monitoring wells and facilities/waste sites discussed in the text.

The following sections describe contaminants of concern, their distribution, how they change with time, and the hydrogeologic framework through which they move.

7.1 CONTAMINANTS OF CONCERN

Contaminants of concern may be chemical or radiological constituents that pose a risk to human and/or ecological receptors. Numerous regulatory requirements, such as the U.S. Environmental Protection Agency's (EPA) drinking water standards (40 CFR 141 "maximum contaminant levels" [MCL]) and ambient water quality criteria (AWQC) for protection of freshwater aquatic organisms, help identify which constituents are of concern.

A limited field investigation (LFI) for the 100-HR-3 Operable Unit identified contaminants of potential concern based on a limited set of data collected in 1992 and 1993. These constituents were used in a qualitative risk assessment, the results of which included recommendations regarding interim remedial measures (IRM). The contaminants of concern, conclusions, and recommendations contained in the LFI report (DOE-RL, 1994c) are as follows:

Operable Unit	Human Health Risk	Ecological Risk	LFI Conclusion and Recommendation
100-HR-3: 100-H Area	Americium-241 Carbon-14 Chromium Chloroform Nitrate Strontium-90 Technetium-99 Tritium Uranium-233/234 Uranium-238	Chromium Sulfide	An IRM is not indicated on the basis of human health or ecological risk. Continue the RI/FS process. Note: Subsequent analysis of data concluded that ecological risk from chromium warranted interim remedial measures.

Source: Limited Field Investigation Report (DOE-RL, 1994c)

These contaminants of concern continue to be tracked primarily by semiannual sampling of wells since the LFI phase of the remedial investigation/feasibility study (RI/FS). As sufficient information becomes available to demonstrate that a constituent is no longer of concern with respect to human health and ecological risk, it is typically removed from the monitoring schedule. However, data for some discontinued contaminants of concern may continue to accumulate, because the constituent is part of a grouped analysis (e.g., an analysis of metals by inductively coupled plasma [ICP]).

Characterization and focused feasibility study (FFS) activities that continued during the final phases of the LFI resulted in a revised assessment of ecological risk because of hexavalent chromium in groundwater near the Columbia River. This led to a decision to proceed with interim remedial measures (IRM) to address chromium contamination (DOE-RL, 1995a and EPA, 1996a). A remedial design/remedial action (RD/RA) work plan (DOE-RL, 1996) describes this IRM, which includes the 100-KR-4 Operable Unit also.

7.1.1 Summary of Current Groundwater Contamination Levels

Table 7-1 presents recently observed concentrations for contaminants of potential concern identified during the LFI, as well as concentrations for additional waste and water quality indicators. This table includes all results contained in the Hanford Environmental Information System (HEIS) database for sampling more recent than January 1, 1995 and is generally inclusive of sampling conducted through January 1996. Semiannual sampling has been the norm since the last half of 1994, so this summary is generally based on two or three sampling events per well.

Initial data evaluation processing has been completed on the entire data set summarized in Table 7-1 (i.e., assigning common units, removing duplicate entries, and correcting known errors in reported results). The full data evaluation process has been completed for chromium, nitrate, strontium-90, tritium, and specific conductance (see Ford and Denslow, 1996 for a description of the evaluation process for data extracted from HEIS).

The list of constituents that currently exceed regulatory standards is similar to the list of contaminants of potential concern identified during the LFI. Chromium, nitrate, strontium-90 (source for gross beta activity), technetium-99 (source for gross beta activity), and uranium (additional source for gross alpha activity) all remain above MCL standards in at least one well in the 100-H Area. Following the initial sampling conducted for the LFI, americium-241, carbon-14, chloroform, and sulfide were dropped from the analysis suite because of nondetections. In addition to the LFI list, aluminum, fluoride, iron, and manganese are elevated above MCL standards. Table 7-2 identifies the 100-H Area wells in which various constituents included in Table 7-1 exceed standards.

7.1.2 Sources for Contamination in Groundwater

The principal surface facilities associated with liquid waste disposal to the soil column are shown in Figure 7-1. A detailed description of these waste-generating facilities is contained in the

100-H Area Technical Baseline Report (Deford and Einan, 1995). A description of how the plutonium production reactors operated is presented in the "Hazards Summary Report" for the production reactor plants (General Electric, 1963). Both documents provide comprehensive background material for interpreting the origin of groundwater contamination. The source information contained in the following summary is derived from those documents, unless otherwise cited.

7.1.2.1 Coolant water retention basins. The 107-H coolant water retention basins introduced a considerable amount of chromium to the soil column and groundwater. These basins received enormous volumes of relatively low concentration (less than 700 $\mu\text{g/L}$) chromium-bearing coolant water. Because of extensive leakage from the basins, mounds 3 to 6 m (10 to 20 ft) higher than the natural water table were created (Brown, 1963). As a result of the radial flow pattern created by mounding, chromium was distributed widely beneath the 100-H Area. Riverbank seepage along the shoreline adjacent to the retention basins was significantly increased during operations.

After operations ceased in the mid-1960s and the mounds dissipated, chromium was likely to remain in the residual moisture left in the normally unsaturated part of the soil column. Residual chromium is expected to diffuse slowly downward for many years, contributing a small but continuous supply of chromium to groundwater (Peterson and Connelly, 1992).

7.1.2.2 Liquid waste disposal trenches. These soil column disposal facilities received used reactor coolant highly contaminated by fuel element ruptures. They were immediately to the south of the retention basins and represent a primary source for radionuclide and chromium contamination. Many radionuclides are adsorbed by sediments in the soil column. This was the primary advantage of using soil column disposal for highly contaminated coolant effluent (instead of direct river discharge via retention basins, as was normal for the reactor coolant effluent stream). However, when a mound was present beneath the retention basins, it is likely that the soil column was not able to scavenge radionuclides from the infiltrating coolant as when a natural water table existed. This is because the rate of groundwater flow was much faster, and fine materials (the major adsorbers of radionuclides) were washed out of the sediments. Consequently, radionuclide movement to the river via groundwater flow and riverbank seepage may still have been appreciable.

7.1.2.3 Miscellaneous disposal facilities near the reactor building. Various acid solutions, including chromic acid, were used to decontaminate equipment associated with reactor operations. These solutions picked up radionuclides and various metals and were typically discharged to small soil column disposal facilities such as cribs, French drains, and trenches located near the 105-H reactor building. While involving much smaller volumes than coolant water discharge, the solutions contained considerably higher chromium concentrations.

7.1.2.4 183-H solar evaporation basins. The 183-H Solar Evaporation Basins, which were remnants of the original 183-H water treatment plant settling basins, were converted for waste management use in 1973. Liquid wastes from nuclear fuel fabrication activities in the 300 Area were trucked to the basins. The wastes consisted primarily of nitric acid that had been

neutralized with sodium hydroxide. They also contained significant amounts of other acids such as chromic, sulfuric, and hydrofluoric acids, and radionuclides, notably isotopes of uranium and technetium. Washdown spillage and, possibly, leakage created a groundwater plume that is monitored under treatment, storage, and disposal (TSD) facility regulations, as mandated by the Resource Conservation and Recovery Act (RCRA). A summary of the facility and its groundwater contamination history is presented in the RCRA Annual Report for 1993 (Peterson, 1994b).

7.1.2.5 Plume migration from the 100-D/DR Area into the 100-H Area. Liquid waste disposal activities in the 100-D/DR Area may have created plumes that migrated across the "horn" of the Hanford Reach toward the 100-H Area. Some groundwater flow from the 100-D/DR Area travels east and northeast across the 600 Area and reaches the Columbia River in the vicinity of the 100-H Area. This flow path was accentuated during operating years when a significant groundwater mound existed under the 107-D retention basins (Brown, 1963; see also Sections 5.0 and 6.0).

Chromium-bearing groundwater from the 100-D/DR Area is the suspected source for elevated chromium observed in two 600 Area wells located between the 100-D/DR and 100-H areas (see Figure 5-2). It is also the likely source for chromium measured in riverbank seepage samples collected in October 1991 from sites immediately upstream of the 100-H Area (DOE-RL, 1992b). A small but consistent increase in estimates for the total amount of chromium in 100-H Area groundwater observed between 1988 and 1992 (Peterson and Connelly, 1992) may be explained by a chromium-bearing water mass that is approaching the 100-H Area.

7.1.2.6 Summary of source operable unit high-priority waste sites. Tabular summaries of waste sites were prepared to support records of decision for source operable units. These summaries include the waste site designator, its physical characteristics, and the contaminants that may be associated with the site. The summaries were originally presented in the Proposed Plans for the 100-HR-1 and 100-HR-2 Operable Units (DOE-RL, 1995k and DOE-RL, 1995l) and are included in this report as Tables 7-3 and 7-4.

7.1.2.7 Summary of liquid waste sites that received chromium. Table 7-5 lists known liquid waste disposal sites within the 100-H Area. The table has been assembled from available information gathered during the RI/FS. It draws heavily on information contained in the 100-H Area Technical Baseline Report (Deford and Einan, 1995).

7.2 CONTAMINANT DISTRIBUTION MAPS AND TREND CHARTS

Chromium, strontium-90, nitrate, and tritium concentrations for data obtained since January 1, 1995 have been plotted on maps to illustrate the current distribution of contamination in 100-H Area groundwater. The maps include water table contours for long-term average elevations, as estimated by measurements for the period from January 1, 1994 through August 30, 1995. Groundwater flow is generally oriented perpendicular to the contour lines.

The concentrations plotted are average values for data from HEIS that have undergone the full data evaluation process (Ford and Denslow, 1996). This process is intended to produce concentration values that accurately represent aquifer conditions. The average values presented do not include results considered nonrepresentative ("outliers") by the data evaluator. Chromium results are for filtered samples, since these data provide the best indicator of chromium dispersed by groundwater flow.

7.2.1 Chromium Contamination

Figure 7-2 illustrates the distribution of chromium in the 100-H Area that is representative of current conditions. Since the shutdown of liquid waste disposal facilities, which was generally complete by the mid-1960s (the exception is 183-H Solar Evaporation Basins), plumes have migrated, dispersed, and discharged into the Columbia River. Currently, plume movement follows the natural hydrologic flow regime, since water table mounds associated with the retention basin have long since dissipated. Chromium concentrations in the plumes dropped quickly during the first years following the shutdown of sources. With time, concentrations have continued to decrease but at a much slower rate. The plumes can be considered "mature," with chromium concentrations in the asymptotic phase of decrease (i.e., low concentrations will continue to be present for many years to come).

The overlying partially saturated soil column may be a "source" that continues to dribble small amounts of chromium into groundwater, thus maintaining these relatively low concentrations. These sediments were saturated with liquid wastes during reactor and waste disposal operations. When operations ceased, the water mounds dissipated, leaving residual contamination in partially saturated sediments--contamination that slowly migrates downward by diffusion. A fluctuating water table, which results from daily and seasonal changes in Columbia River stage, periodically resaturates sediments immediately above the water table. Any residual contamination remaining in these sediments may be remobilized. As the water table falls, water carrying contaminants from these sediments drains into the aquifer. Contaminants in the aquifer then travel and discharge into the river.

Trend charts showing the change in chromium concentration with time have been prepared for three groups of wells: (1) wells included in the vicinity of the IRM extraction network, (2) additional near-river wells, and 3) inland wells. Figure 7-3 shows trends for the first group. Wells H4-12A and H4-4 are located close to the river, and fluctuations in river level strongly influence the composition of water samples from these wells. Well 199-H4-3 is a downgradient monitoring well in the 183-H Solar Evaporation Basins network. The well was sampled throughout the operating period of the basins (1973 to 1985). (The basins are no longer in service; they were demolished in 1995.) Data from sampling this well provide an excellent history for the development and dissipation of a chromium plume, but that's another story.

Well 199-H4-12C (Figure 7-3) has revealed consistently high concentrations of chromium since its installation in 1987. The well has an open sampling interval approximately 34 to 44 ft (m) below the water table and is completed in the Ringold Formation Upper Mud Unit, which is believed to be isolated from contamination in the uppermost unconfined aquifer.

Co-contaminants that might indicate contamination from the 183-H Basins, such as nitrate and radionuclides, are not elevated in this well.

Previous attempts to explain the source for chromium in well 199-H4-12C usually resort to it being associated with well construction. For instance, corrosion of stainless steel at weld points in the screen has been shown to elevate chromium and nickel in samples, especially if chloride is elevated in the groundwater (Oakley and Korte, 1996). However, chromium was monitored during drawdown tests in this well, and concentrations did not decrease as expected if chromium was being produced in the well screen. The water chemistry in the well does not vary with river stage fluctuations, as does chemistry in other near-river wells (including 199-H4-12A). The relatively high chromium concentrations in 199-H4-12C remain enigmatic.

Figure 7-4 shows trends for additional near-river wells. Well 199-H4-10 is screened in very transmissive sediments; the river exerts a strong influence on water levels and water quality in this well. Because the well is located upgradient from known 100-H Area chromium sources, the observed chromium is suspected of having its origin at the 100-D/DR Area, as is the chromium observed in well 199-H4-17.

Figure 7-5 shows concentration trends for wells located inland from the river. Wells 199-H3-2A and 199-H4-49 provide an indication that chromium-laden groundwater from the 100-D/DR Area sources may be reaching the 100-H Area, since recent analytical results show an increase in concentrations. Well 699-96-43, which is located upgradient of the 100-H Area in the 600 Area, monitors the groundwater that is approaching the 100-H Area from the west.

Samples of river substrate pore water were collected along the 100-H Area shoreline during March and April 1995 (Hope and Peterson, 1996a). Figure 7-6 shows the results for chromium analyses on these samples. Only two locations showed concentrations that are elevated above EPA criteria for protection of aquatic organisms (i.e., 11 $\mu\text{g/L}$). One area is adjacent to the 107-H Retention Basin and is also immediately downstream of the reactor coolant outfall structure. The second site is an isolated detection at transect 14 (Figure 7-6), for which there is no obvious explanation, since adjacent sampling sites do not reveal chromium.

Additional monitoring of river substrate pore water was under way during September 1996 to further characterize the occurrence of chromium at transect 1 (Figure 7-6). Sampling tubes were being driven into the substrate at multiple depths (up to 30 in.), and access tubes were emplaced that lead onshore to above the high water shoreline, thus allowing sample collection at any river level.

7.2.2 Strontium-90 Contamination

The distribution of strontium-90 in the 100-H Area is shown in Figure 7-7. Strontium-90 appears to be elevated above the 8 pCi/L MCL standard in the vicinity of the 107-H Retention Basin, which is expected, based on historical information for retention basin operation. With the possible exception of well 199-H6-1, concentrations in other wells near the basin are decreasing (Figure 7-8).

7.2.3 Nitrate Contamination

Nitrate concentrations in the 100-H Area are shown in Figure 7-9. Nitrate concentrations are generally below the 45,000 $\mu\text{g/L}$ MCL standard, with the exception of the hot spot that remains near the 183-H Solar Evaporation Basins. Nitric acid was a principal component of the wastes placed into the basins. The distribution of nitrate has provided a clear indicator of the extent of the plume emanating from the basins in the past (Peterson, 1994b). Since use of the basins stopped in 1985, the plume has dissipated and its boundaries have become less well-defined.

Nitrate trends in the four wells that best defined the limits of the 183-H basins' plume are shown in Figure 7-10. Well 199-H4-3, which is located immediately downgradient of the basins, is the most sensitive indicator of contamination associated with the basins. Some of the variability observed in this well has been attributed to fluctuations in the water table. As the water table rises, residual contamination in the partially saturated zone becomes fully saturated and much more mobile. This well's elevated contaminant concentrations have been observed to follow increases in the water table elevation.

An abrupt change in nitrate concentrations that occurred in early 1993 was observed in many wells in the 100 Area. The change is believed to be related to a variance in methods used to purge the well prior to sampling. These changes are described more fully in the 183-H Solar Basins annual reports (e.g., Peterson, 1994b; Hartman, 1995b).

Well 199-H4-4 is further downgradient from the 183-H basins than 199-H4-3. Nitrate concentrations show variability directly related to fluctuating river levels (Figure 7-10). The nitrate trend in 199-H4-4 (chromium trend also; see Figure 7-3) provides an example of the difficulty encountered in obtaining representative samples from near-river wells. The timing of sampling must be closely coordinated with the river stage if a sample representative of aquifer conditions is to be obtained.

7.2.4 Fluoride Contamination

Fluoride was a common component of wastes placed in the 183-H Solar Evaporation Basins. During demolition of the basins in 1995, soils beneath the basins were sampled and excavated when contamination from leakage was encountered. The two constituents in the soil samples that exceeded standards were nitrate and fluoride.

Trend charts for fluoride in the four wells that formerly defined the 183-H groundwater plume are presented in Figure 7-11. The MCL standard for fluoride is 1,400 $\mu\text{g/L}$; concentrations in well 199-H4-3 occasionally exceed that value.

7.2.5 Tritium Contamination

Tritium concentrations are shown in Figure 7-12. Tritium is not elevated above MCL standards (20,000 pCi/L) but is included in this report because it is frequently used to describe the movement of contaminants. Trend charts for tritium in wells located near the western edge of

the 100-H Area are shown in Figure 7-13. The increases in tritium in these wells may be additional evidence for the movement into the 100-H Area of contaminated water that originated in the 100-D/DR Area.

7.3 HYDROGEOLOGY

This section describes the framework through which contaminants may be transported by groundwater movement. The following sections describe the lithologies of the stratigraphic units and the saturated and unsaturated zones, as well as the physical properties of the various hydro-stratigraphic units.

7.3.1 Hanford and Ringold Stratigraphic Units

The most important stratigraphic units underlying the 100-H Area are the Hanford formation and the upper units of the Ringold Formation. Figures 7-14 and 7-15 show geologic cross sections oriented parallel to groundwater flow and normal to the Columbia River channel. Figure 7-16 shows a cross section oriented approximately parallel to the Columbia River. These cross sections show the Hanford-Ringold contact, graphically display sediments recovered during drilling of the groundwater monitoring wells, and show the range in depth to groundwater during the period from January 1, 1994, to August 30, 1995. (Refer to Figure 7-1 for the trace of the three geologic cross sections through the 100-H reactor area in the 100-HR-3 groundwater operable unit.)

7.3.1.1 Hanford formation. The Hanford formation in the 100-H Area is dominated by sandy gravel and gravelly sand, with local sandy and silty interbeds (see Figures 7-14 through 7-16). The Hanford formation is 12.2 to 18.3 m (40 to 60 ft) thick throughout most of the 100-H Area, with a minimum thickness of 9.8 m (32 ft) in 199-H4-17 and a maximum thickness of 19.2 m (63 ft) in 199-H4-2, east of the 105-H Reactor.

7.3.1.2 Ringold Formation. The Ringold Formation in the 100-H Area includes the Upper Mud, the underlying Unit B, and the Lower Mud. The Upper Mud was penetrated completely by wells 199-H3-2C, 199-H4-2, 199-H4-12C, and 199-H4-15C and varies in thickness, from a maximum of about 44.2 m (145 ft) in 199-H4-12C to a minimum of 24.4 m (80 ft) in 199-H4-15C. It is an overbank Unit Composed of silt, sandy silt, and gravelly silt with sandy interbeds. (For additional details regarding Unit B and the Lower Mud in the 100-H Reactor Area, see Lindsey and Jaeger (1993).)

The contact between the Hanford formation and the underlying Ringold Formation was designated as the first silt-dominated beds of the Upper Mud overbank deposits. The contact is highest west of the 100-H Area and slopes toward the Columbia River to the east. A north-south-oriented Ringold Formation erosional remnant is present in the central part of the site. This erosional remnant is about parallel to the Columbia River channel, suggesting that it was formed by differential erosion associated with flooding (Lindsey and Jaeger, 1993).

7.3.2 Vadose Zone and Uppermost Aquifer

The vadose zone varies in thickness from approximately 13.5 m (44 ft) in 199-H3-1 to 12.8 m (42 ft) in 199-H4-13, near the Columbia River (see Figures 7-14 and 7-15). These figures show the water table is located in the lower Hanford formation. Therefore, it follows that the uppermost aquifer is within the lower Hanford formation because the Ringold upper mud is an aquitard. The saturated thickness of the uppermost aquifer ranges from 6.4 m (21 ft) in 199-H4-4 to 0.78 m (2.55 ft) in 199-H4-17, based on average groundwater elevations in wells during the period from January 1, 1994, to August 30, 1995.

100-H Area geologic sections (Figures 7-14 through 7-16) show maximum and minimum groundwater elevations of the top of the uppermost aquifer. These are calculated from monitoring well measurements from January 1, 1994, to August 30, 1995. Wells near the Columbia River, such as 199-H4-4, range up to 1.89 m (6.2 ft) in groundwater elevation, while wells inland, such as 199-H5-1, vary as little as 0.30 m (1 ft). The range in groundwater elevation near the river is largely due to the effect of river stage.

Figure 7-2 shows the elevation of the water table developed from average elevations in wells measured from January 1, 1994, to August 30, 1995. The flow direction is to the east, with a gradient of 0.00106.

A vertical (upward) hydraulic gradient between the Ringold Formation upper mud and the Hanford formation uppermost aquifer is not consistent in the 100-H Area as shown on Figures 7-17 and 7-18, hydrographs of shallow and deep wells. Clustered wells (e.g., 199-H4-12A, B, and C; 199-H4-15A, B, and C; and 199-H3-2A, B, and C) were designed with screens in at least two hydrogeologic units. However, as seen in Table 7-6, groundwater elevations are very similar in nested wells with well screens in the Hanford formation and Ringold Upper Mud. An upward gradient does exist between the Ringold Formation Lower Mud and the Hanford formation because wells screened in the Ringold Lower Mud or the basalt show a head above the land surface.

7.3.3 River Influence on Monitoring Wells

Water level elevations and specific conductance are used to qualitatively evaluate the influence the river has on monitoring wells. Table 7-7 summarizes water level elevations and specific conductance for each 100-H Area well, and shows the well's distance inland from the river's low-water shoreline. The wells are separated into two groups in the table: (1) those that have screened or perforated open intervals that include the water table and (2) those that are open at depths in the aquifer well below the water table.

Data for Table 7-7 were extracted from HEIS in the form of depth-to-water measurements. These values were combined with recent top-of-casing surveys, using either results from an extensive 1993 U.S. Army Corps of Engineers survey, or, when Corps data are not available, results from a recent ICF Kaiser Hanford, Inc., survey. These surveys are referenced to baseline

monuments, the locations of which were re-established by the Corps in 1993. All data are referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

The average water level elevation is for data obtained during the period from January 1, 1994, through August 30, 1995. This average represents long-term conditions over slightly more than a seasonal cycle. The range between minimum and maximum water level elevations provides a measure of the degree to which river stage fluctuations influence the well. The range is also influenced by the degree to which the aquifer segment intercepted by the well is confined. In response to river fluctuations, more-confined segments produce greater changes in well water levels.

Values for specific conductance are also included in Table 7-7. Specific conductance, which varies with the amount of dissolved salts in the groundwater, can be used to identify water of various origins. River water is typically in the range of 120 to 140 $\mu\text{S}/\text{cm}$. Groundwater from the Hanford gravels is approximately 400 $\mu\text{S}/\text{cm}$, while water from the Ringold Formation appears to be approximately 300 $\mu\text{S}/\text{cm}$, although data to support the latter are limited. Given these contrasts, specific conductance is useful in helping to describe the interaction between river water and groundwater. However, where contamination is present, specific conductance may vary over a wide range, thus reducing its usefulness as a mixing indicator for natural waters.

7.3.4 Aquifer Properties

Slug tests were conducted in seven wells in the 100-H Area during the LFI. The results were analyzed in accordance with Bouwer and Rice (1976) and Bouwer (1989). Table 7-8 includes hydraulic conductivities from slug test data collected from wells drilled during the LFI and screened in the Hanford formation (DOE-RL, 1994c). Hydraulic conductivities varied from 0.0247 cm/sec (70 ft/d) in 199-H6-1 to 0.0423 cm/sec (120 ft/d) in 199-H4-46.

Aquifer drawdown tests were performed by the Pacific National Northwest Laboratory (PNNL) in 1987 as part of the 183-H Solar Evaporation Basin characterization. A second series of drawdown tests was performed by the Environmental Restoration Contractor (ERC) in 1995 to assess candidate wells for the 100-HR-3 IRM pump-and-treat system. The ERC tests were of adequate duration to confirm hydraulic conductivity and transmissivity determined during the PNNL tests. The drawdown tests conducted by PNNL in wells 199-H3-2A, 199-H4-4, 199-H4-10, 199-H4-11, 199-H4-12C, 199-H4-14, and 199-H4-15C resulted in a wide range of hydraulic conductivities, from 2.09 cm/sec (5,940 ft/day) in 199-H4-10 to 0.025 cm/sec (71 ft/day) in 199-H4-11. Both wells are screened in the Hanford formation (see Hartman and Peterson, 1992).

7.3.5 Physical Properties of Aquifer Materials

Table 7-9 is a summary of physical-properties testing conducted on nine samples collected in the Hanford formation from wells 199-H4-45, 199-H4-46, and 199-H5-1. Samples are classified by hydrogeologic designation (e.g., vadose), by sediment description, and by stratigraphic unit.

[illegible]

Figure 7-2. Chromium Distribution in the 100-H Area

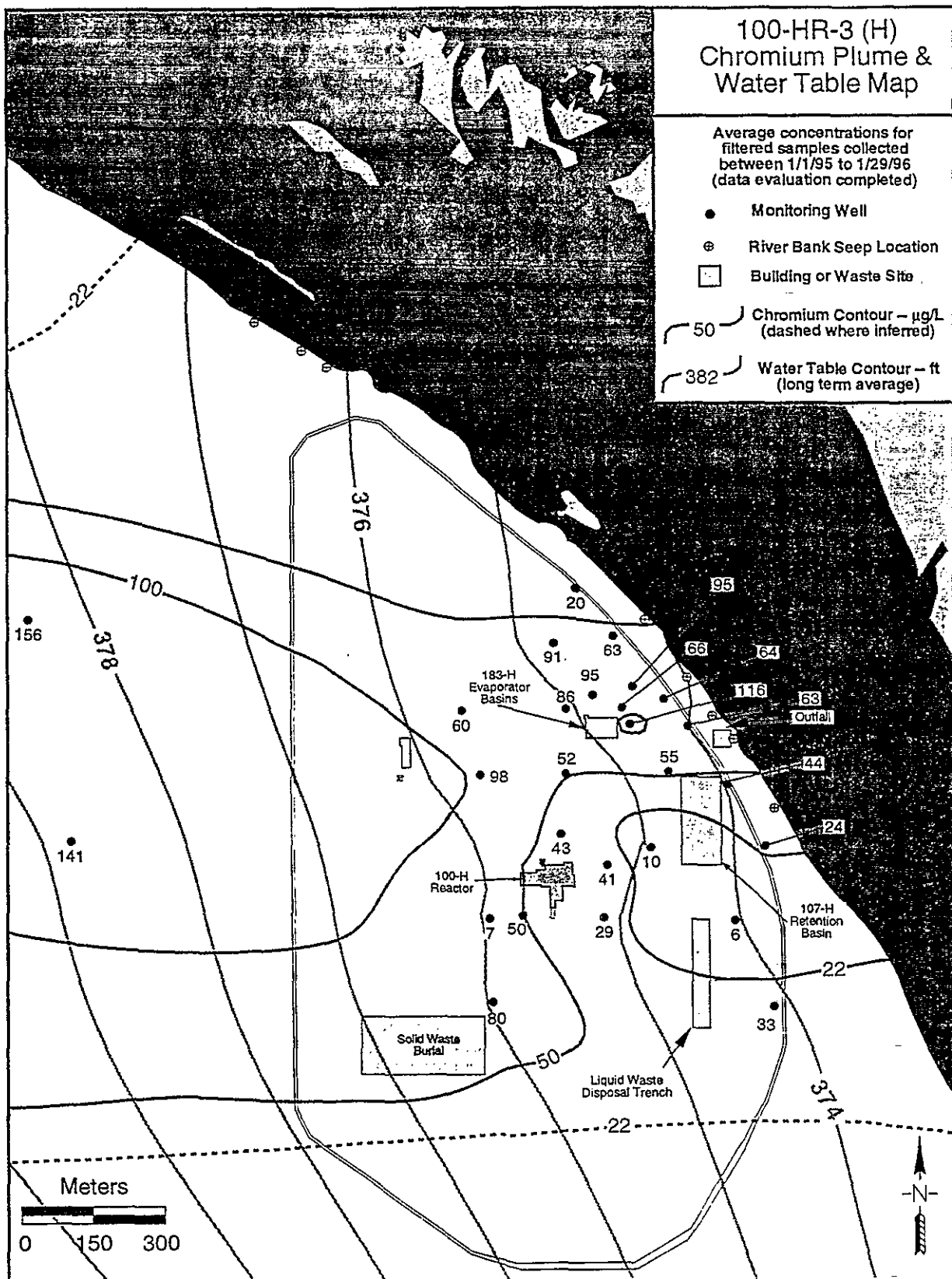


Figure 7-3. Chromium Trends in Selected 100-H Area IRM Network Wells

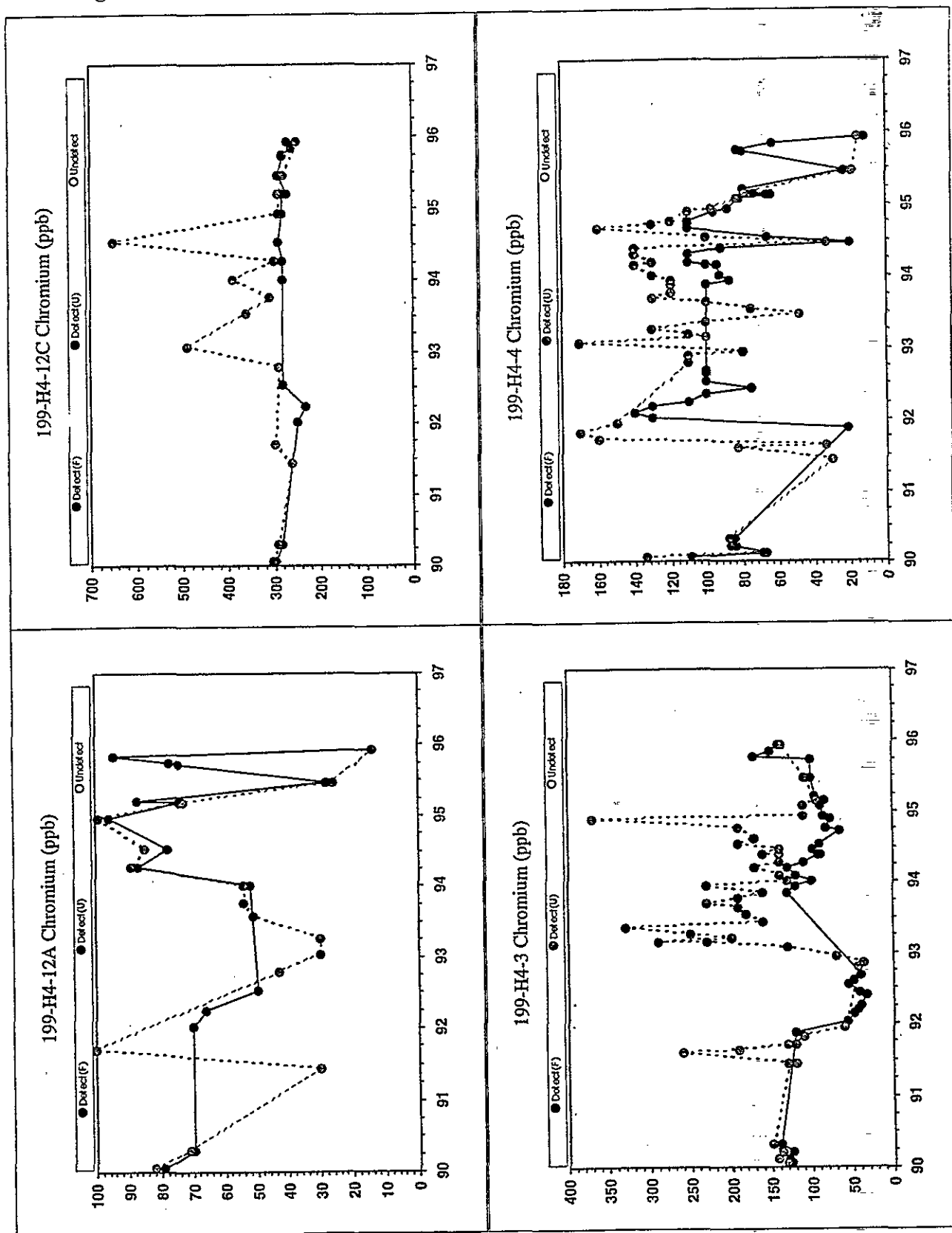


Figure 7-4. Chromium Trends in Selected 100-H Area Near-River Wells

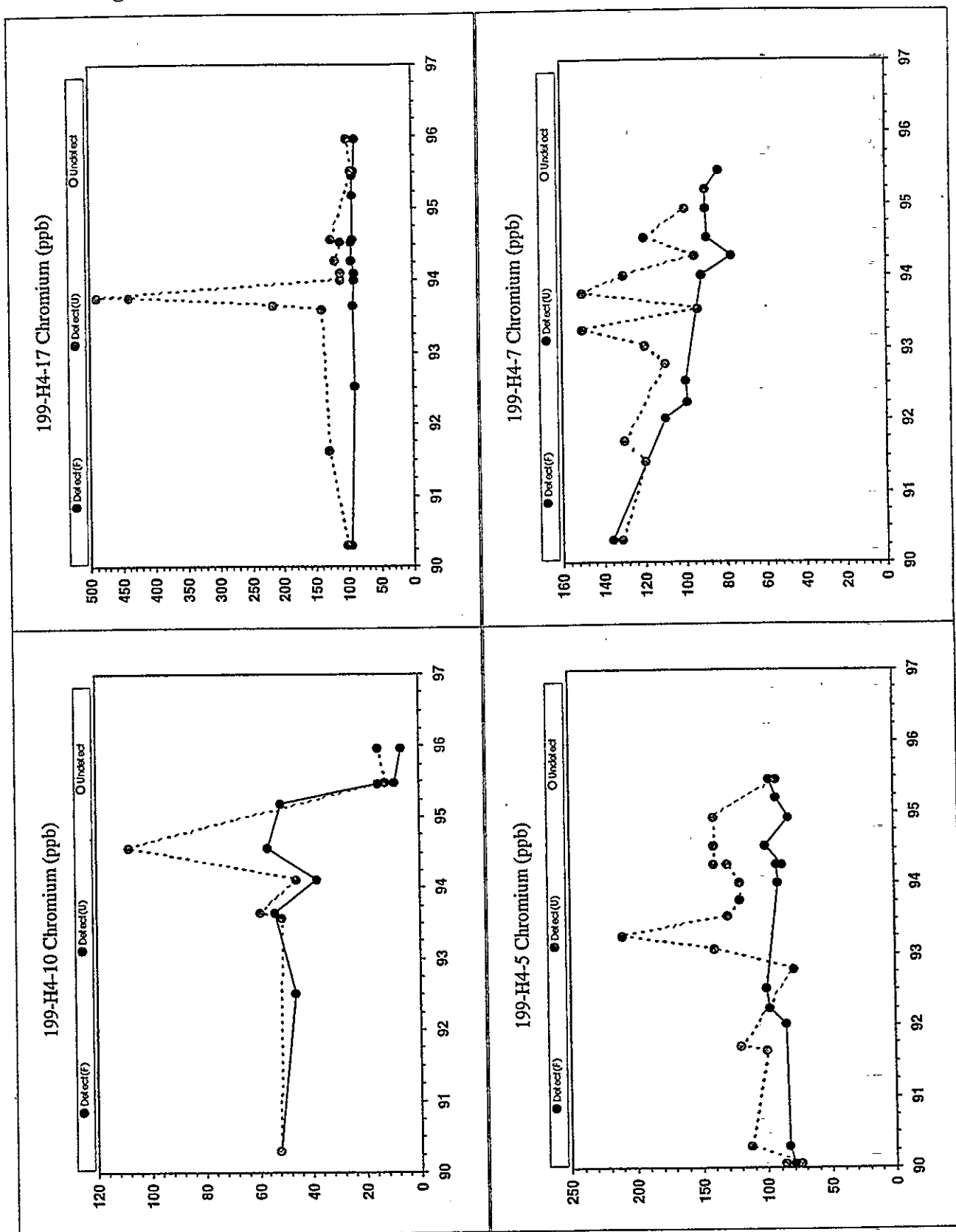
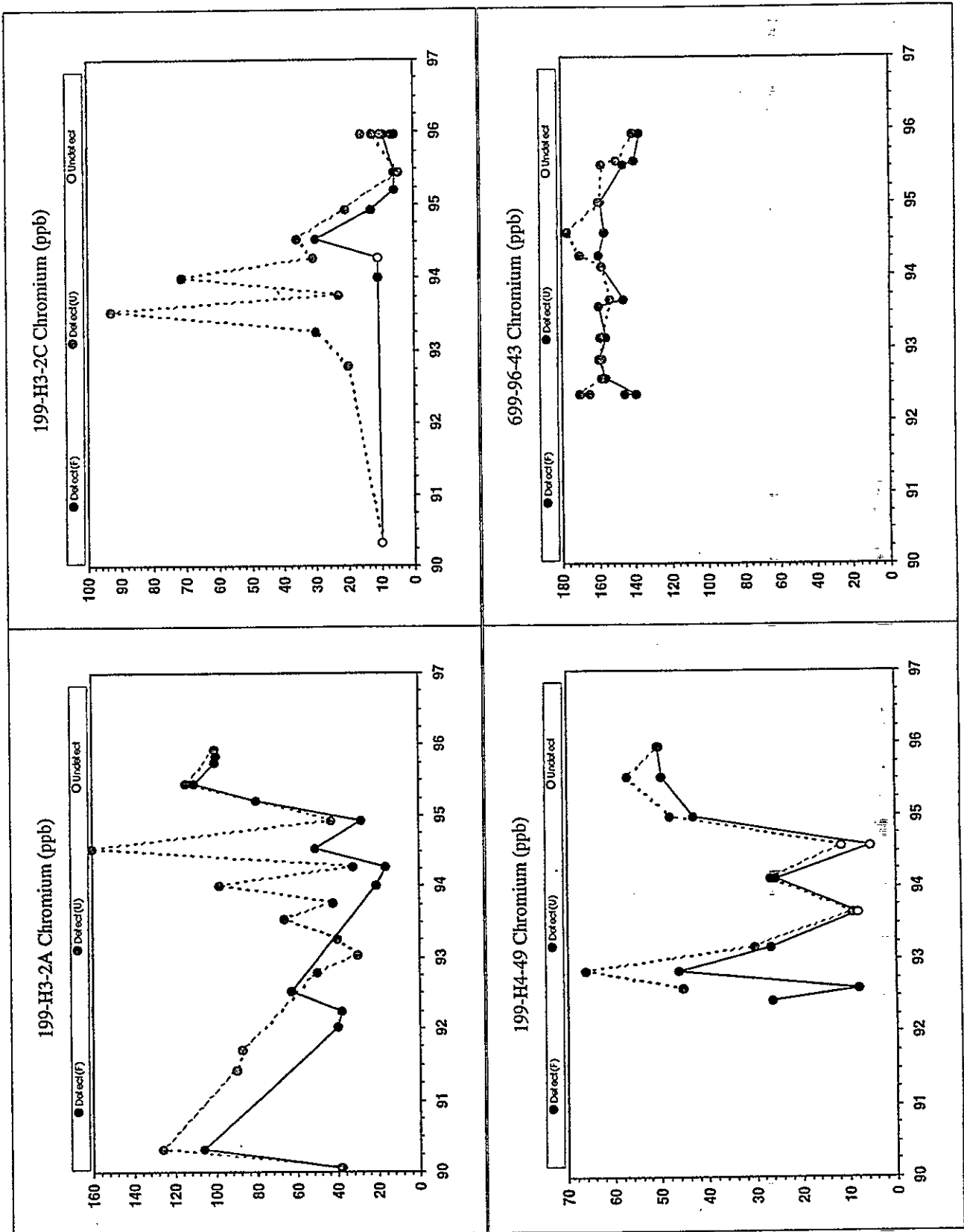


Figure 7-5. Chromium Trends in Selected 100-H Area Inland Wells



100-H Area River Substrate Pore Water Results (March / April, 1995)

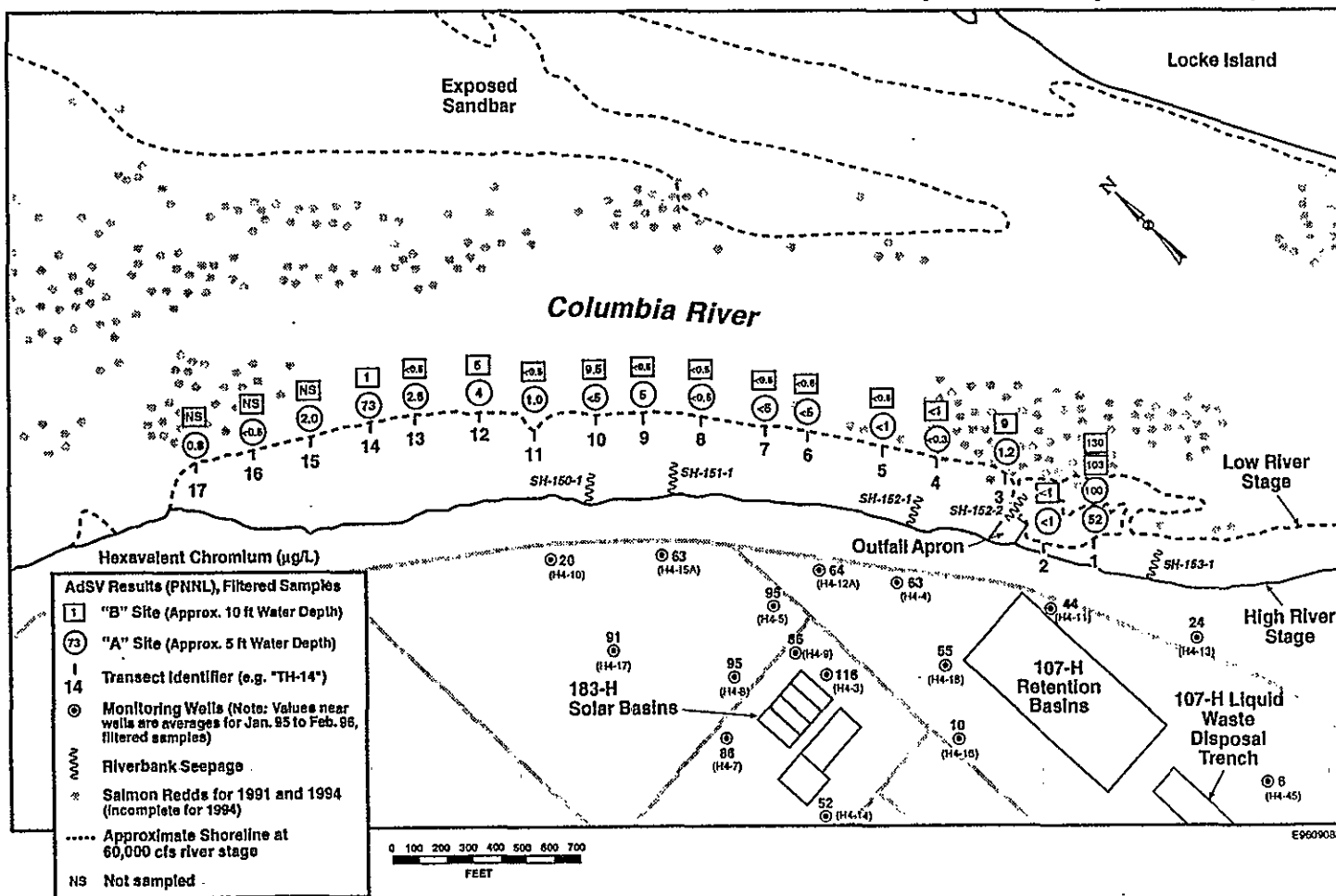


Figure 7-6. Chromium in River Substrate Pore Water in the 100-H Area (Hope and Peterson, 1996a)

**100-HR-3 (H)
Strontium-90 Plume &
Water Table Map**

Average concentrations for
samples collected between
1/1/95 to 12/19/95
(data evaluation completed)

- Monitoring Well
- ⊙ River Bank Seep Location
- Building or Waste Site

50 Sr-90 Contour -- pCi/L
(dashed where inferred)

382 Water Table Contour -- ft
(long term average)

100-H Reactor

183-H Evaporator Basins

107-H Retention Basin

Liquid Waste Disposal Trench

Solid Waste Burial

Outfall

374 376 378 380 382

0 150 300 Meters

N

Figure 7-8. Strontium-90 Trends in Selected 100-H Area Wells

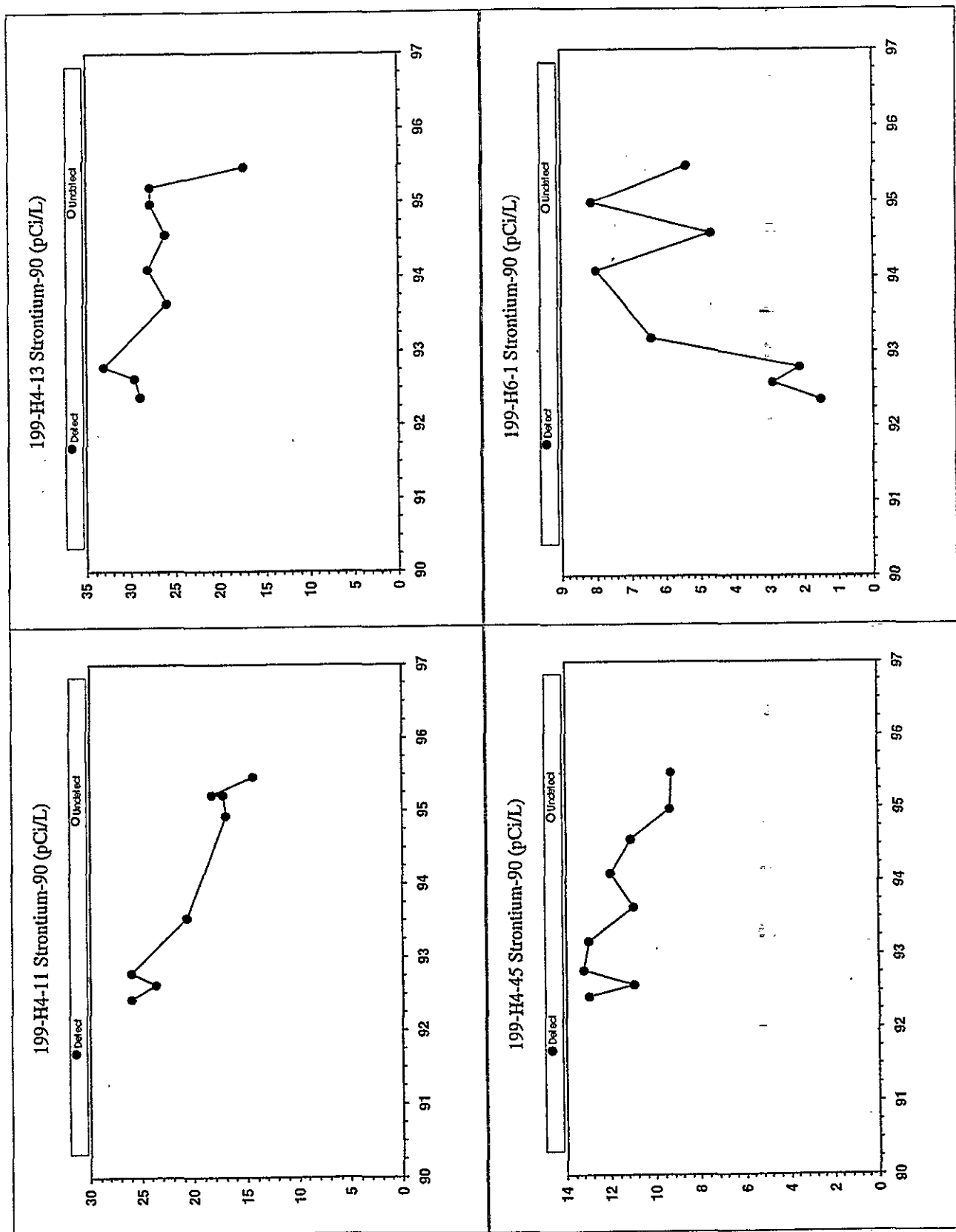


Figure 7-9. Nitrate Distribution in the 100-H Area

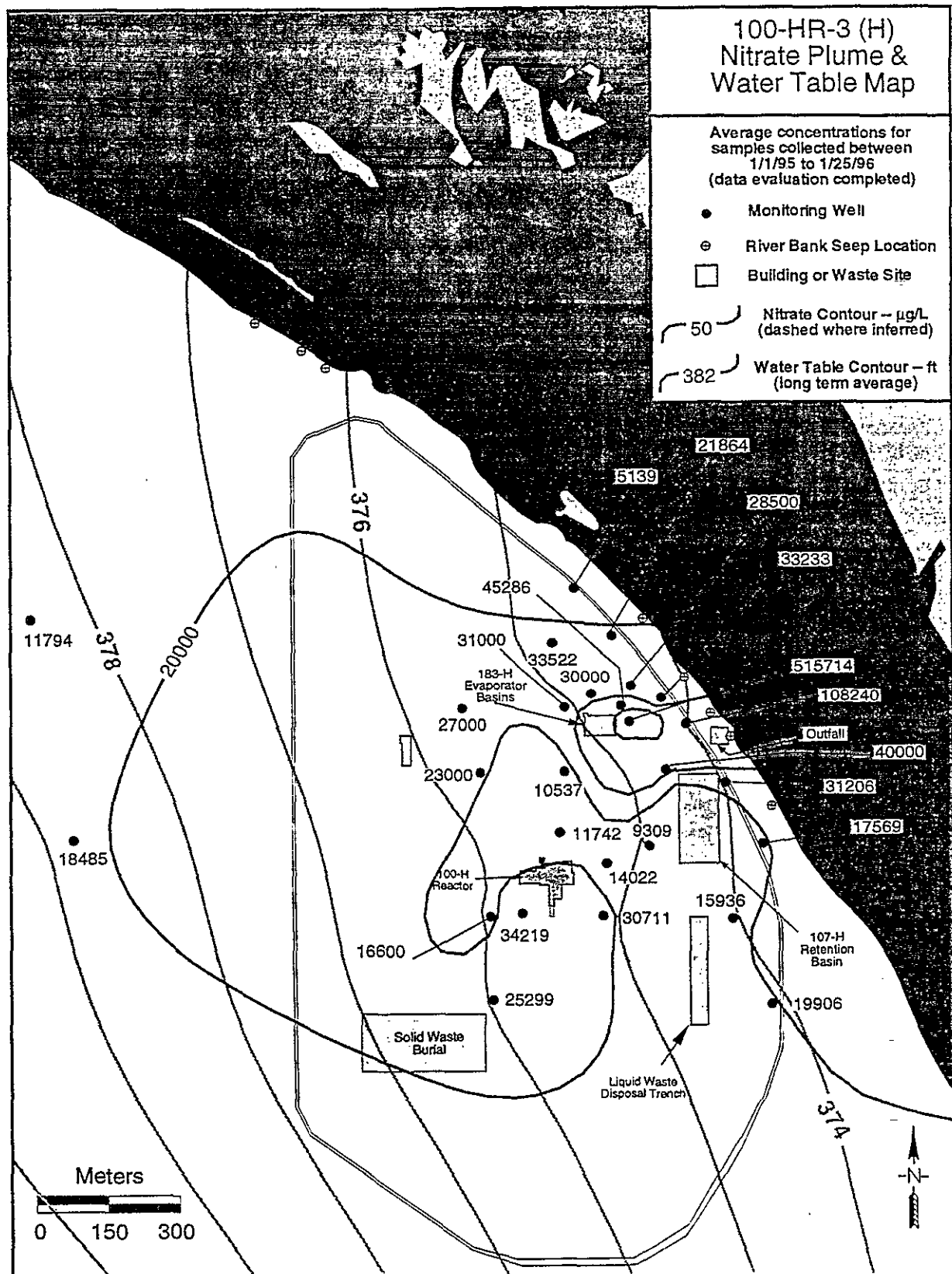
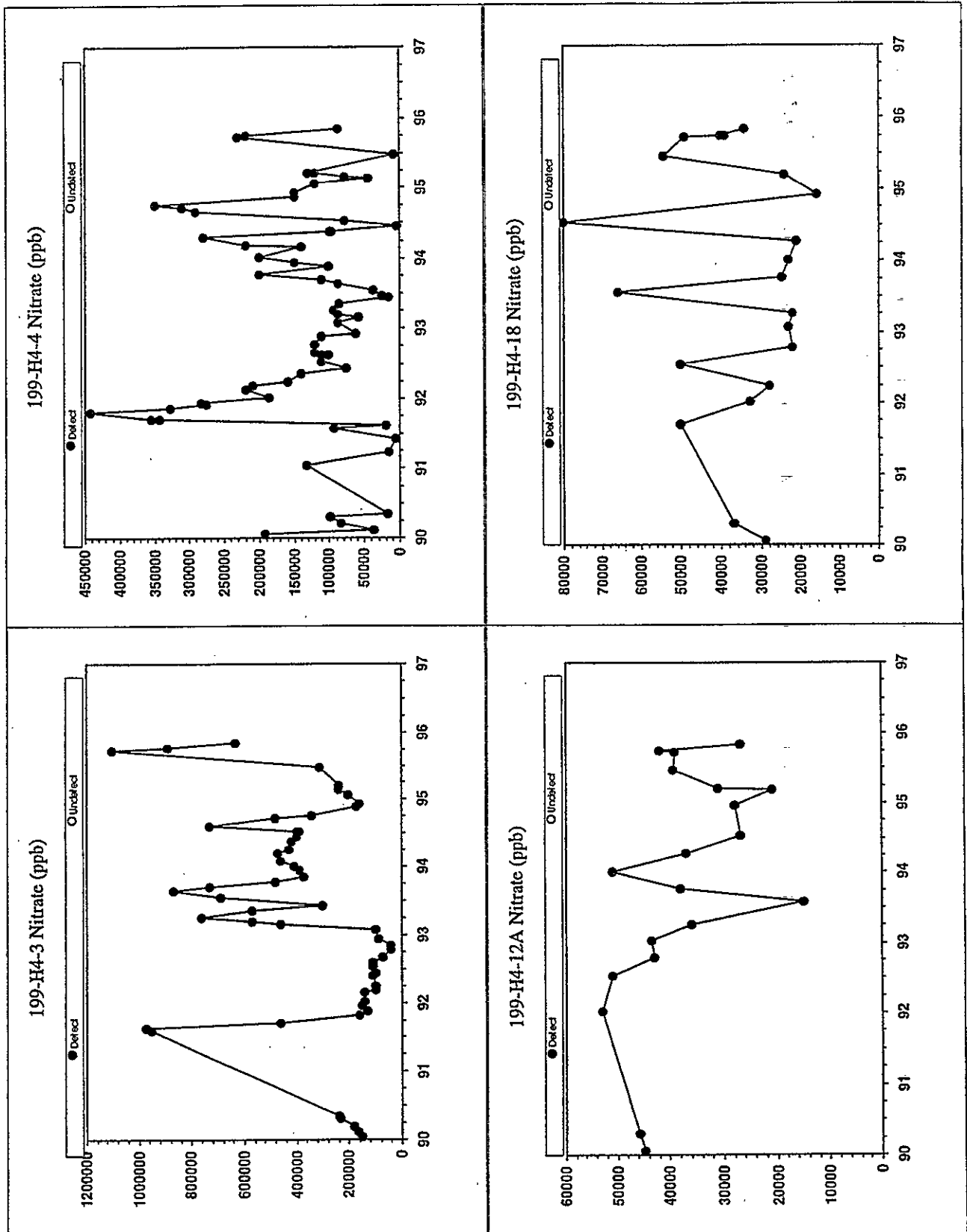


Figure 7-10. Nitrate Trends in 183-H Basins Monitoring Wells



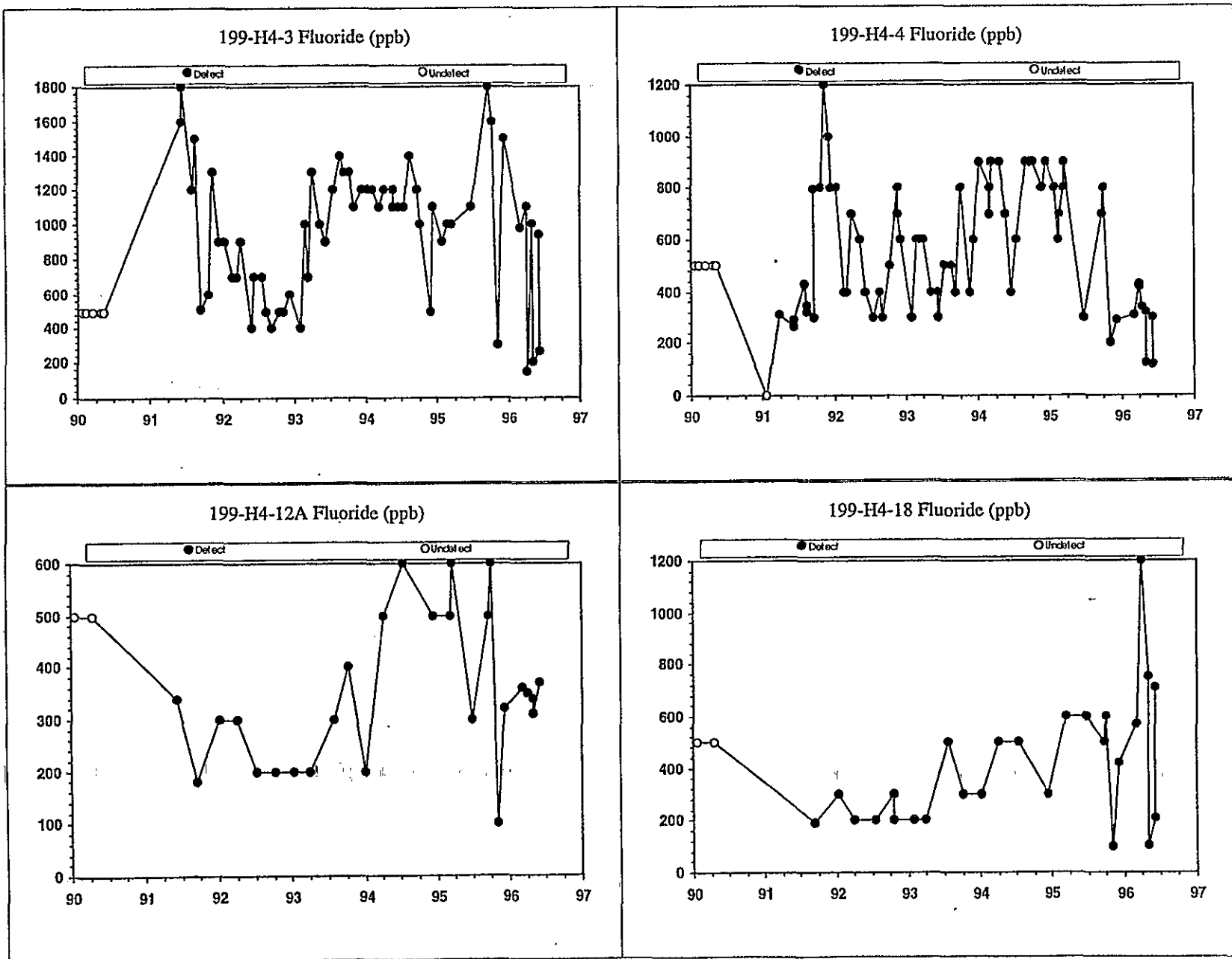


Figure 7-11. Fluoride Trends in 183-H Basins Monitoring Wells

Figure 7-12 Tritium Distribution in the 100-H Area

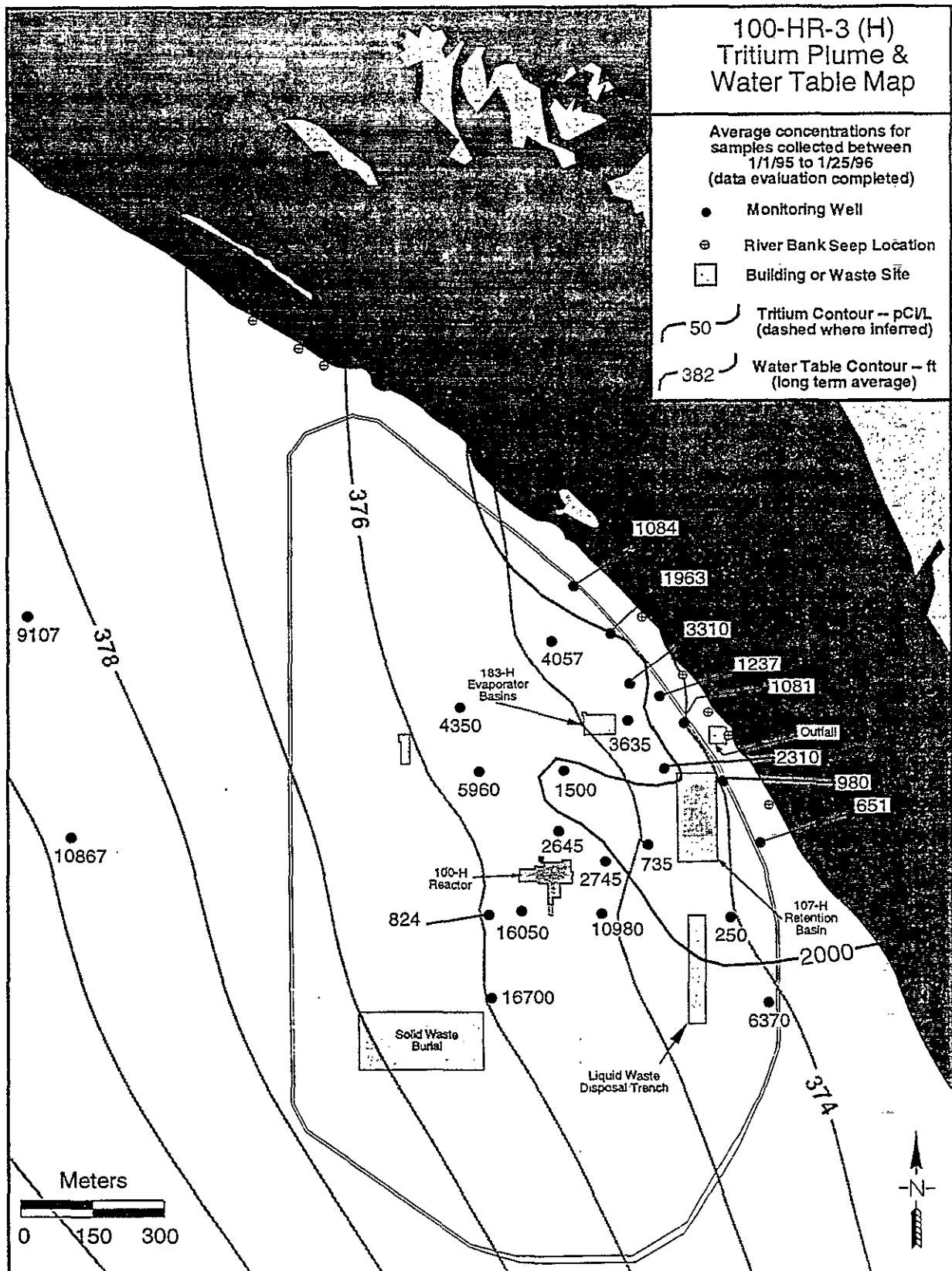


Figure 7-13. Tritium Trends in Selected 100-H Area Inland Wells

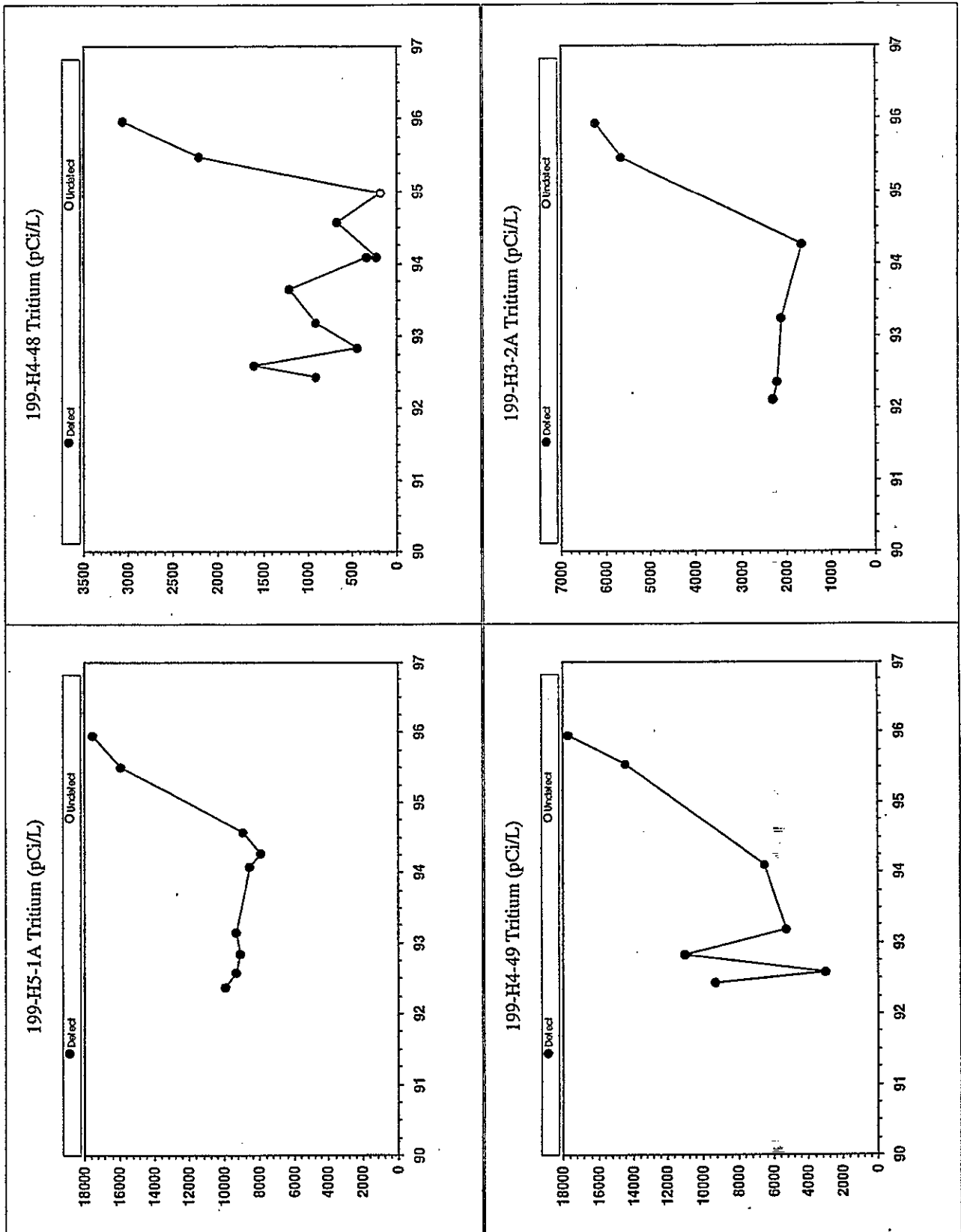


Figure 7-14. Cross Section (A-A') Perpendicular to the 100-H Area Shoreline

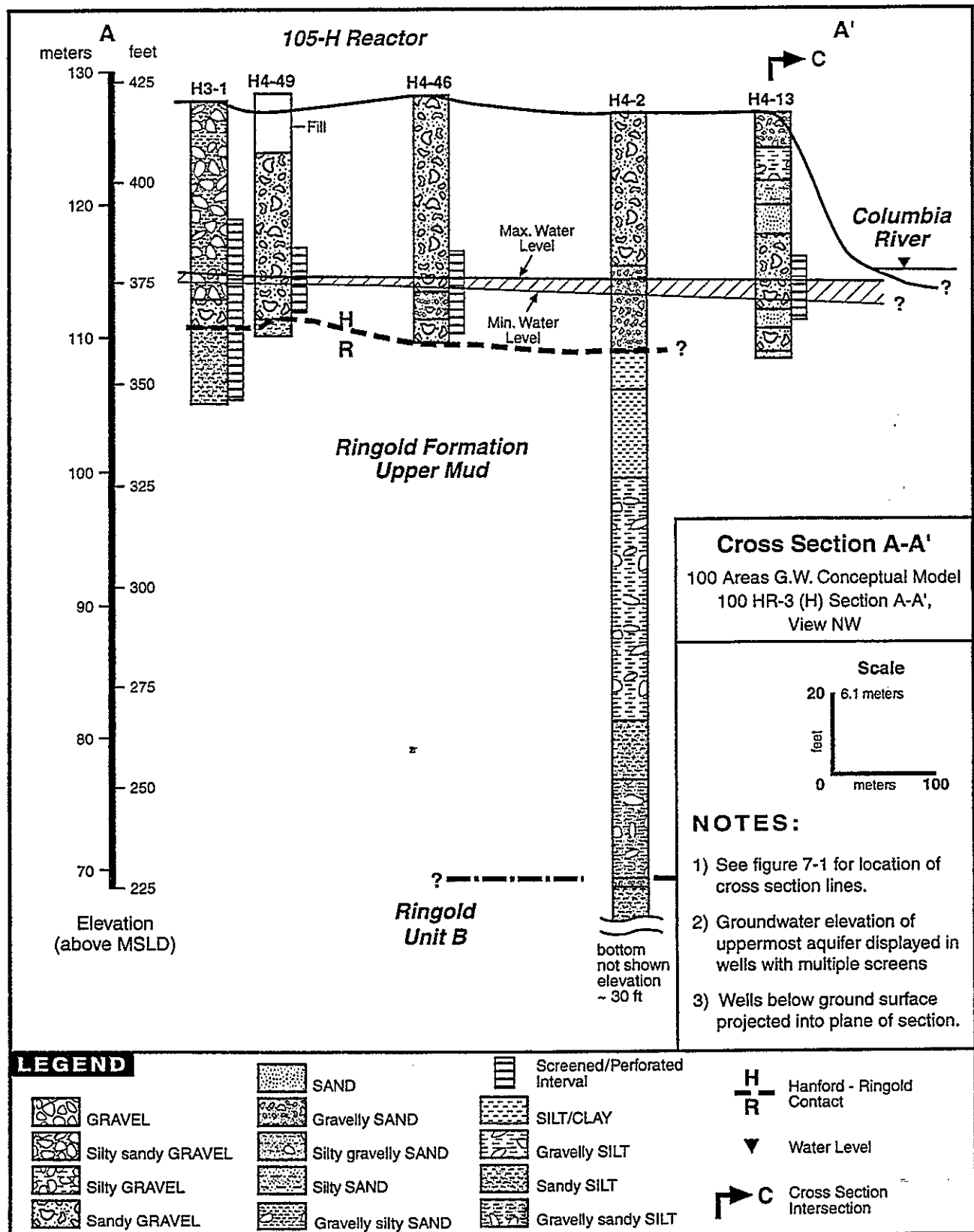
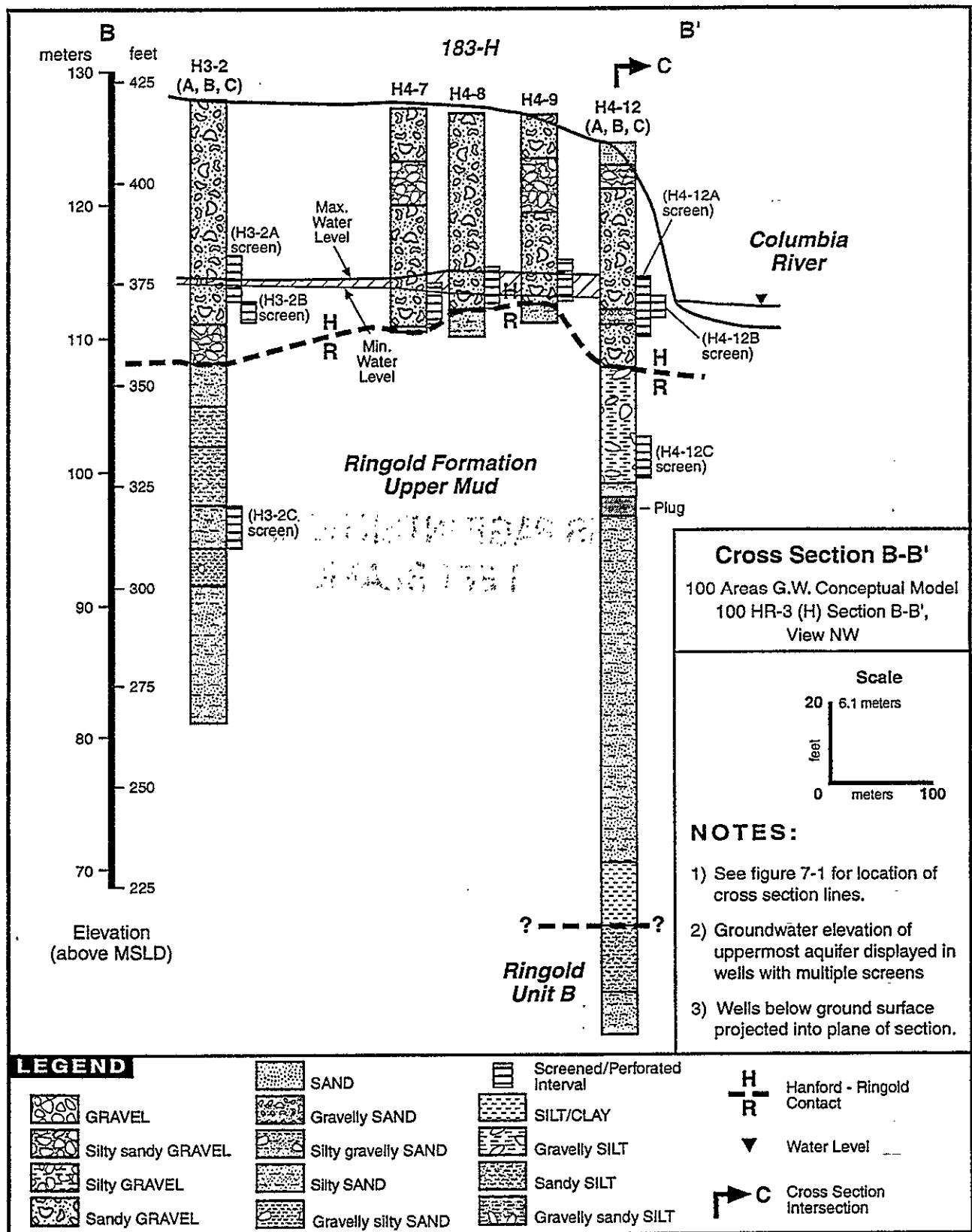


Figure 7-15. Cross Section (B-B') Perpendicular to the 100-H Area Shoreline



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Figure 7-16. Cross Section (C-C') Parallel to the 100-H Area Shoreline

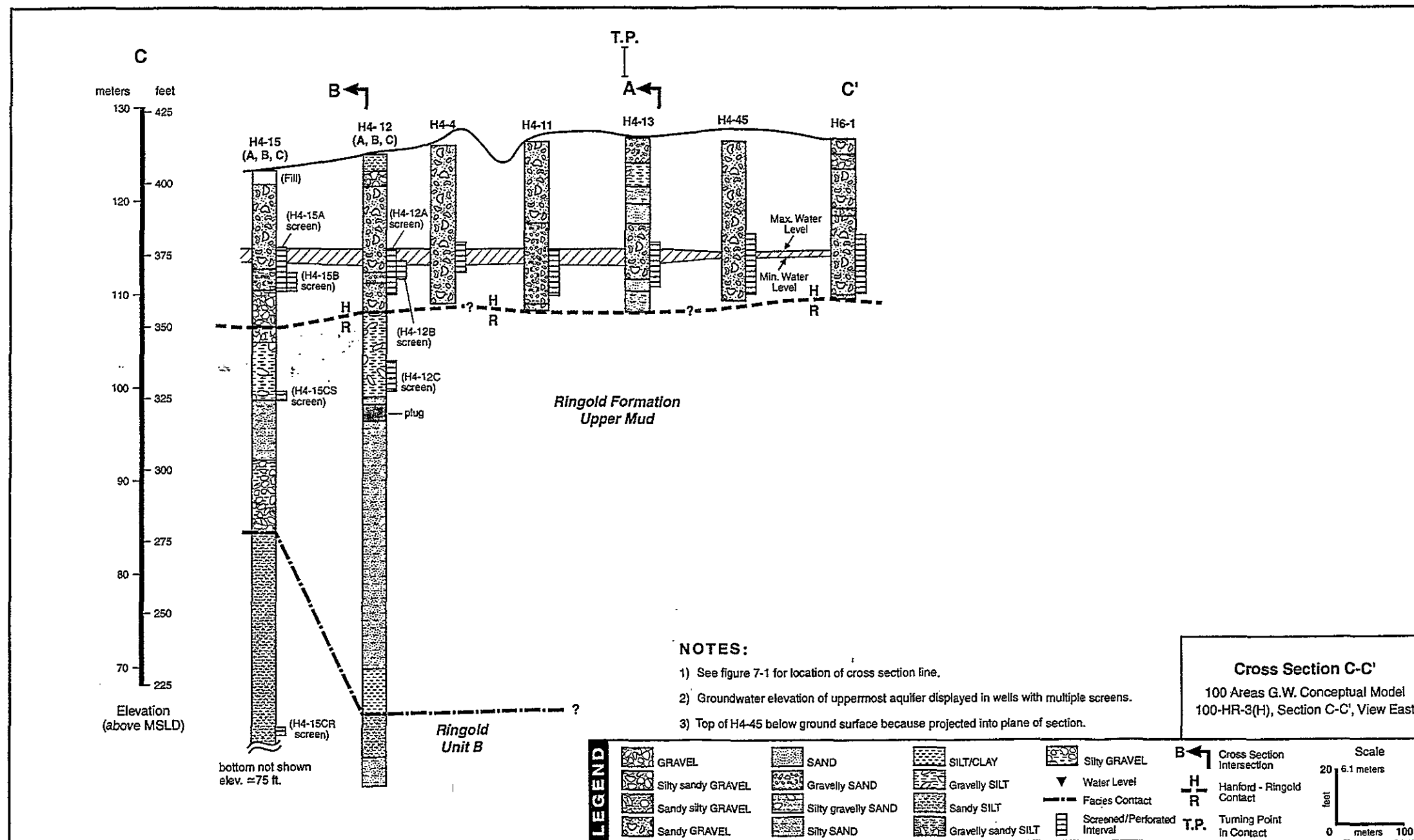


Figure 7-17. Hydrographs For Near-River Shallow and Deep Wells in the 100-H Area

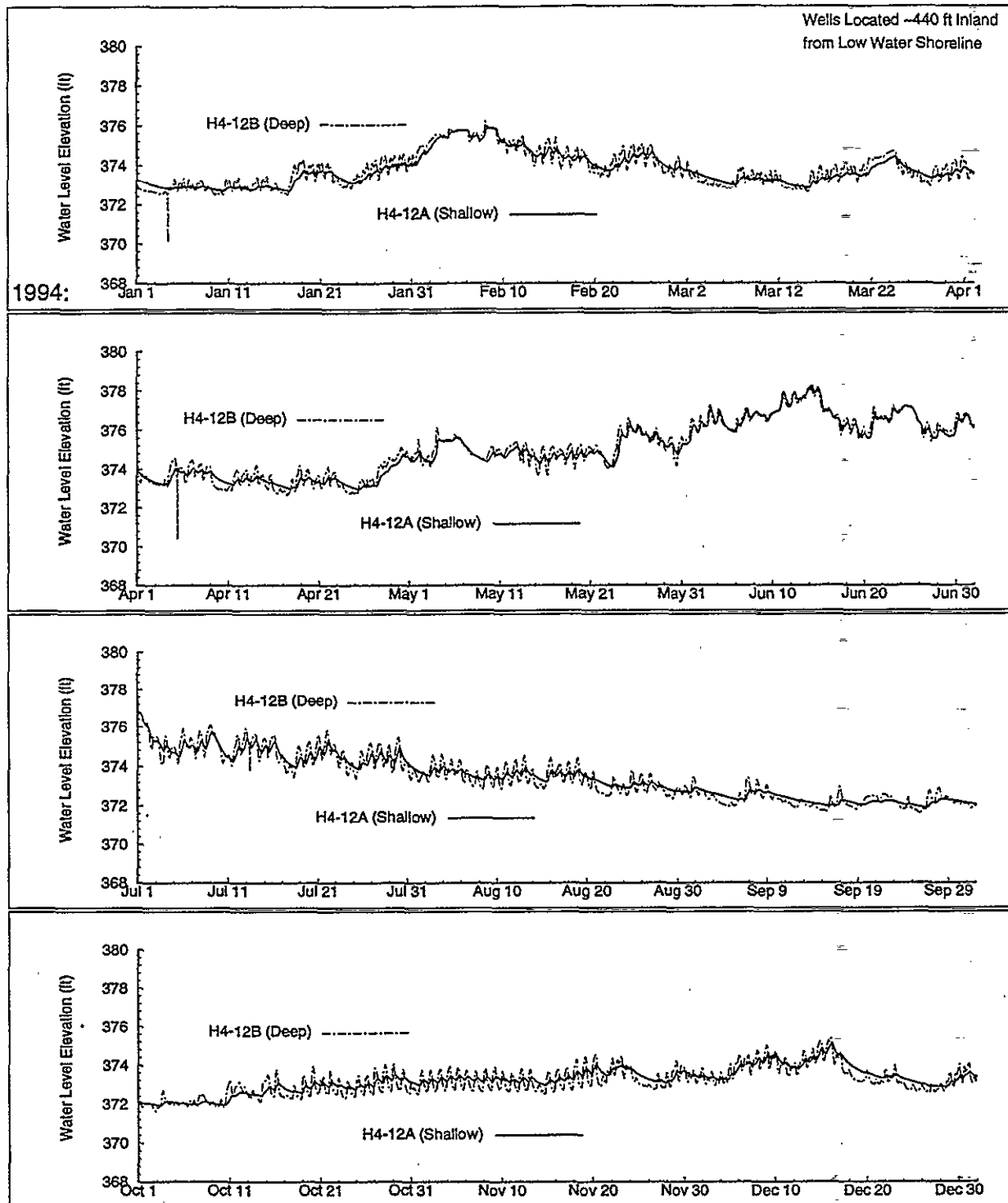
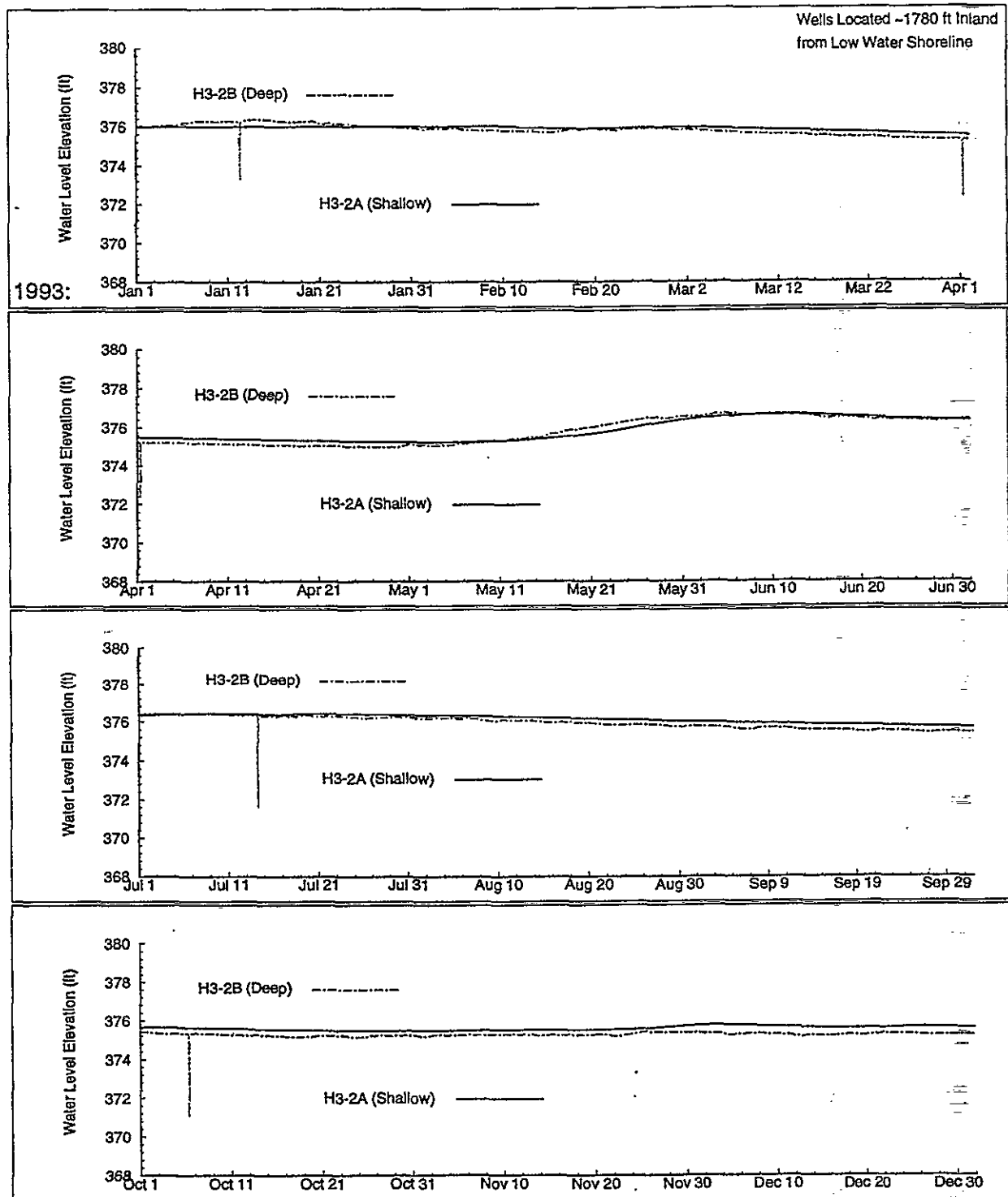


Figure 7-18. Hydrographs for Inland Shallow and Deep Wells in the 100-H Area



100-HR-3 (H) Chemical Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
1,1,1-Trichloroethane	ppb	N	2	4	0	0.00	0.00	0.00	200	MCL	0	0	
Aluminum	ppb	N	32	83	27	25.70	1900.00	124.53	50	SMCL	12	0	
Aluminum	ppb	Y	37	175	22	16.00	82.00	36.52	50	SMCL	2	2	6.86
Arsenic	ppb	N	3	3	0	0.00	0.00	0.00	50	MCL	0	0	
Arsenic	ppb	Y	2	2	0	0.00	0.00	0.00	50	MCL	0	0	8.06
Barium	ppb	N	32	83	82	12.80	94.00	36.61	1000	MCL	0	0	
Barium	ppb	Y	37	175	174	6.10	190.00	40.49	1000	MCL	0	0	91.57
Cadmium	ppb	N	32	83	8	1.30	4.70	2.95	10	MCL	0	0	
Cadmium	ppb	Y	37	175	11	1.20	4.20	2.35	10	MCL	0	0	3.07
Chloride	ppb	N	37	190	190	4.39	18700.00	6542.13	250000	SMCL	0	0	16863.99
Chromium	ppb	N	32	83	81	4.60	390.00	78.67	50	MCL	45	0	
Chromium	ppb	Y	37	173	170	5.50	290.00	72.56	50	MCL	104	24	16.61
Copper	ppb	N	32	83	43	2.40	176.00	16.36	1300	MCL-P	0	0	
Copper	ppb	Y	37	175	60	2.10	66.30	9.49	1300	MCL-P	0	0	0.85
Fluoride	ppb	N	37	167	166	100.00	1800.00	505.52	1400	MCL	3	1	904.00
Iron	ppb	N	32	83	69	17.00	6200.00	273.44	300	SMCL	7	0	
Iron	ppb	Y	37	175	136	9.00	4900.00	85.27	300	SMCL	4	4	415.86
Lead	ppb	N	4	4	0	0.00	0.00	0.00	50	MCL	0	0	
Lead	ppb	Y	2	2	0	0.00	0.00	0.00	50	MCL	0	0	3.47
Manganese	ppb	N	32	83	55	0.78	230.00	13.04	50	SMCL	3	0	
Manganese	ppb	Y	37	175	93	0.37	210.00	10.26	50	SMCL	5	2	40.11
Nickel	ppb	N	32	83	7	14.00	170.00	40.44	100	MCL	1	0	
Nickel	ppb	Y	37	175	21	7.70	49.50	18.72	100	MCL	0	0	2.19
Nitrate	ppb	N	37	227	227	9.34	1100000.00	53043.50	45000	MCL	36	5	31725.97
Selenium	ppb	N	3	3	0	0.00	0.00	0.00	10	MCL	0	0	
Selenium	ppb	Y	2	2	0	0.00	0.00	0.00	10	MCL	0	0	6.01
Silver	ppb	N	32	83	12	2.40	5.70	3.78	50	MCL	0	0	
Silver	ppb	Y	37	175	3	3.50	4.90	4.07	50	MCL	0	0	5.68
Sulfate	ppb	N	37	190	190	28.00	120000.00	44601.20	250000	SMCL	0	0	84676.12
Trichloroethene	ppb	N	2	4	0	0.00	0.00	0.00	5	MCL	0	0	
Uranium	ppb	N	24	121	119	0.64	273.00	21.44	44	UMTR	15	2	9.28
Uranium	ppb	Y	1	1	1	3.25	3.25	3.25	44	UMTR	0	0	9.28
Zinc	ppb	N	32	83	62	6.50	218.00	26.09	5000	SMCL	0	0	21.47
Zinc	ppb	Y	37	175	78	3.90	97.70	15.19	5000	SMCL	0	0	21.47

Table 7-1. Constituents Summary for the 100-HR-3 (H) Operable Unit (Page 1 of 2)

Table 7-1. Constituents Summary for the 100-HR-3 (H) Operable Unit (Page 2 of 2)

100-HR-3 (H) General Properties

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Dissolved Oxygen	mg/L	N	27	47	47	0.00	11.50	6.14			0	0	14935.41
pH Measurement	pH	N	38	185	185	6.58	11.90	7.91			0	0	8.07
Specific Conductance	umhos/cm	N	38	193	193	1.03	2590.00	477.44			0	0	428.00
Temperature	Deg C	N	38	185	185	12.00	29.50	17.94			0	0	

100-HR-3 (H) Radiological Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Carbon-14	pCi/L	N	20	22	9	4.19	32.40	11.98	2000	MCL	0	0	152.79
Gross alpha	pCi/L	N	34	91	72	1.06	51.00	7.12	15	MCL	11	3	2.47
Gross beta	pCi/L	N	34	91	88	2.03	577.00	35.49	50	MCL	12	4	7.44
Strontium-89/90	pCi/L	N	27	30	11	1.05	19.50	6.80			0	0	0.02
Strontium-90	pCi/L	N	28	35	14	0.00	27.70	9.90	8	MCL	7	3	0.02
Technetium-99	pCi/L	N	34	145	75	0.00	4980.00	470.28	900	MCL	15	4	1.78
Tritium	pCi/L	N	35	91	83	0.00	17700.00	3455.23	20000	MCL	0	0	162.00
Uranium-233/234	pCi/L	N	1	1	1	1.47	1.47	1.47			0	0	1.48
Uranium-234	pCi/L	N	24	33	32	0.37	15.00	2.93			0	0	
Uranium-235	pCi/L	N	24	34	18	0.01	1.42	0.29			0	0	0.08
Uranium-238	pCi/L	N	24	34	33	0.34	11.00	2.23			0	0	1.28

Data Source: Hanford Environmental Information System. Abbreviations: MCL = EPA maximum contaminant level (primary); MCL-P = EPA maximum contaminant level (proposed); SMCL = EPA maximum contaminant level (secondary); EPA 440/5-86-001-USEPA Freshwater Chronic Water Quality Criteria; and UMTR = Uranium Mining Tailings Reclamation. "Background Values" are provisional 90th percentile values taken from Hanford Site Background: Part 3, Groundwater (DOE/RL-96-91, Decisional Draft)

Table 7-2. Constituents in 100-H Area Wells that Exceed Standards (Page 1 of 2)

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Aluminum (50 µg/L)	199-H4-4 199-H4-9	82 58	400 720	Possible source is filter backwash--alum was used extensively in water treatment
Chromium (50 µg/L)	199-H3-2A 199-H3-2B 199-H4-10 199-H4-12A 199-HR-12B 199-H4-12C 199-H4-14 199-H4-15A 199-H4-15B 199-H4-15C 199-H4-17 199-H4-18 199-H4-3 199-H4-4 199-H4-48 199-H4-49 199-H4-5 199-H4-6 199-H4-7 199-H4-8 199-H4-9 199-H5-1A 699-96-43 699-97-43	110 90 51 94 91 290 66 100 110 86 93 120 170 83 51 51 97 87 90 97 81 84 146 160	1,780 1,780 410 440 440 430 1,300 460 460 460 810 710 730 400 1,610 2,110 560 1,610 1,050 810 720 2,660 3,990 2,660	Widespread contaminant in 100-H Area groundwater, with multiple sources. Major sources included reactor coolant effluent, decontamination solutions, and leakage from the 183-H Solar Evaporation Basins. Groundwater migrating into the 100-H Area from the west contains chromium, whose source is likely to be past disposal in the 100-D/DR Area.
Fluoride (1,400 µg/L)	199-H4-3	1,800	730	Constituent in 183-H Solar Evaporation Basins wastes.
Gross Alpha (15 pCi/L)	199-H4-15A 199-H4-3 199-H4-4	16 51 35	460 730 400	Probably reflects uranium in 183-H Solar Evaporation Basins wastes.
Gross Beta (50 pCi/L)	199-H4-11 199-H4-18 199-H4-3 199-H4-4	71 89 577 156	420 710 730 400	Probably reflects technetium-99 in 183-H Solar Evaporation Basins wastes, and strontium-90 from the retention basins.
Iron (300 µg/L)	199-H4-14 199-H4-17 199-H4-6 699-90-45	1,210 759 600 4,900	1,300 810 1,610 (tbd)	Common in Hanford sediments--naturally occurring. May be associated with carbon-steel well casing.
Manganese (50 µg/L)	199-H4-6 699-90-45	210 210	1,610 (tbd)	Common in Hanford sediments--naturally occurring. May be associated with carbon-steel well casing.

Table 7-2. Constituents in 100-H Area Wells that Exceed Standards (Page 2 of 2)

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Nitrate (45,000 $\mu\text{g/L}$)	199-H4-11	46,924	420	Widespread, multiple sources, including decontamination solution disposal near the reactor building, and leakage from the 183-H Solar Evaporation Basins.
	199-H4-18	580,000	710	
	199-H4-3	1,100,000	730	
	199-H4-4	230,000	400	
	199-H4-9	60,000	720	
Strontium-90 (8 pCi/L)	199-H4-11	18	420	Associated with leakage from the retention basins.
	199-H4-13	28	500	
	199-H4-45	9	960	
Technetium-99 (900 pCi/L)	199-H4-12A	1,312	440	Constituent in 183-H Solar Evaporation Basins waste.
	199-H4-18	2,303	710	
	199-H4-3	4,980	730	
	199-H4-4	923	400	
Uranium (44 $\mu\text{g/L}$)	199-H4-3	273	730	Constituent in 183-H Solar Evaporation Basins waste.
	199-H4-4	80	400	

Table 7-3. 100-HR-1 Source Operable Unit High-Priority Waste Sites

Waste Site	Physical Waste Site Description	Former Waste Site Use	¹ Contaminants of Potential Concern
116-H-7 Retention Basin	Reinforced rectangular concrete retention basin. 193 m long x 84 m wide x 6 m deep.	Held effluent from 105-H Reactor for cooling and decay of short-lived radionuclides before being released to the Columbia River. Large leaks occurred during operation and underlying soil was contaminated.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, K-40, Ra-226, Sr-90, Th-228, U-238, arsenic, chromium, lead, zinc
116-H-1 Process Effluent Trench	Unlined trench. 59 m long x 34 m wide x 5 m deep.	Received reactor cooling water made radioactive through contact with failed fuel elements. Received sludge from 116-H-7 Retention Basin when 105-H Reactor was deactivated.	Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-239/240, K-40, Ra-226, Sr-90, Th-228, arsenic, chromium
100-H Buried Process Effluent Pipelines	Buried parallel process effluent pipelines; total length of 1.5 m diameter piping is 902 m; total length of 0.5 m piping is 325 m. Buried up to 6 m below surface; no known soil contamination.	Transported reactor cooling water from the 105-H Reactor to the 116-H-7 Retention Basin, 116-H-5 Outfall Structure, and 116-H-1 Process Effluent Trench. The pipelines may contain contaminated sludge and scale.	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Ni-63, Pu-238, Pu-239/240, Sr-90, U-238
116-H-4 Pluto Crib	Unlined crib. 3 m long x 3 m wide x 3 m deep; crib was excavated and removed in 1960 to allow construction of the 132-H-2 filter building.	Received reactor cooling water contaminated by failed fuel elements. Crib was excavated and material buried in 118-H-5 Burial Ground. A filter building (132-H-2) was later built on the 116-H-4 Pluto Crib site.	None identified in Qualitative Risk Assessment

Cs-134	=	¹³⁴ Cesium
Cs-137	=	¹³⁷ Cesium
Co-60	=	⁶⁰ Cobalt
Eu-152	=	¹⁵² Europium
Eu-154	=	¹⁵⁴ Europium
Eu-155	=	¹⁵⁵ Europium
K-40	=	⁴⁰ Potassium
Ni-63	=	⁶³ Nickel
Pu-238	=	²³⁸ Plutonium
Pu-239/240	=	^{239/240} Plutonium
Ra-226	=	²²⁶ Radium
Sr-90	=	⁹⁰ Strontium
Th-228	=	²²⁸ Thorium
U-238	=	²³⁸ Uranium

¹ The contaminants of potential concern were identified from the Qualitative Risk Assessment (QRA).

Table 7-4. 100-HR-2 Source Operable Unit High-Priority Waste Sites

Waste Site Name/Number	Physical Description	Date of Use	Former Use	Contaminants of Potential Concern
118-H-1 Burial Ground	213 m x 107 m x 6 m deep; estimated volume and area of contaminated soil are 15,381 m ³ and 22,752 m ² , respectively.	1949-65	Contains irradiated and contaminated reactor safety equipment and various pieces of hardware as well as nonradioactive solid waste. All trenches and pits have been backfilled and stabilized with clean soil to prevent exposure to surface radiation.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, cadmium, lead, mercury
118-H-2 Burial Ground	30.5 m x 42.7 m x 3 m deep; estimated volume and area of contaminated soil are 2,904 m ³ and 656 m ² , respectively.	1955-65	Contains irradiated and contaminated hardware associated with an experimental reactor test facility. It consists of two concrete vaults that received radioactive solid waste. Both vaults have been backfilled and stabilized with clean soil to prevent exposure to surface radiation.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, cadmium, lead, mercury
118-H-3 Burial Ground	30.5 m x 114.4 m x 95.5 m x 122 m x 6 m deep; estimated volume and area of contaminated soil are 3,159 m ³ and 8,210 m ² , respectively.	1953-57	Contains components and hardware from reactor modification programs. All trenches have been backfilled and stabilized with clean soil to prevent exposure to surface radiation.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, cadmium, lead, mercury
118-H-4 Burial Ground	45.7 m x 9.2 m x 3 m deep; estimated volume and area of contaminated soil are 802 m ³ and 418 m ² , respectively.	1953	Contains irradiated reactor safety equipment and hardware associated with its removal from the reactor. The trench has been backfilled and stabilized with clean soil to prevent exposure to surface radiation.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, cadmium, lead, mercury
118-H-5 Burial Ground	9.2 m x 0.6 m x 1.5 m deep; estimated volume and area of contaminated soil are 8.47 m ³ and 5.57 m ² , respectively.	1953 and 1960	Contains irradiated experimental reactor safety equipment. It also contains soil from the 116-H-4 Pluto Crib. The Pluto Crib was an earthen pit that received an estimated 260 gallons of radioactive liquid waste. The liquid waste consisted of contaminated cooling water from reactor process tubes. The burial ground has been backfilled and stabilized with clean soil to prevent exposure to surface radiation.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, Ra-226, cadmium, lead, mercury
Buried Thimble Site	12.2 m x 2.1 m x 1.4 m deep; estimated volume and area of contaminated soil are 11.33 m ³ and 7.4 m ² , respectively.	Unknown	Suspected to contain a component of the reactor safety system. The area has been covered with clean soil. There is a radioactive surface contamination barricade around a small portion of the area.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, cadmium, lead, mercury
105-H Rod Cave	(12.2 m) x 0.6 m x 1.5 m deep; estimated volume and area of contaminated soil are 35.7 m ³ and 26 m ² , respectively.	Unknown (appears in aerial photographs as early as 1950).	Used for temporary storage of irradiated reactor safety equipment. These pieces of hardware were usually contaminated. Lead bricks have been stacked to form one wall, and the roof is covered with gravel and is not visible.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Sr-90, cadmium, lead, mercury

C-14 = ¹⁴Carbon
Cs-137 = ¹³⁷Cesium
Co-60 = ⁶⁰Cobalt
Eu-152 = ¹⁵²Europium
Eu-154 = ¹⁵⁴Europium

Eu-155 = ¹⁵⁵Europium
H-3 = Tritium
Ni-63 = ⁶³Nickel
Ra-226 = ²²⁶Radium
Sr-90 = ⁹⁰Strontium

Table 7-5. Known Facility Sources for Chromium in the 100-H Area

Waste Site Number	Facility Name	Operating Period	Liquid Effluent Summary
116-H-1	107-H Liquid Waste Disposal Trench	1952-58; 1965	90 million liters of highly contaminated reactor coolant from fuel element ruptures; 90 kg sodium dichromate; retention basin sludge and water (1965)
116-H-2	1608-H Liquid Waste Disposal Trench	1953-65	600 million liters of coolant; 600 kg of sodium dichromate
116-H-3	105-H Dummy Decontamination French Drains	1950-65	400,000 liters of nitric acid; 2,000 kg sodium dichromate
116-H-4	Original 105-H Pluto Crib Site	1950-52	1,000 liters of contaminated coolant; 1,000 kg sodium dichromate (suspected too high)
116-H-5	1904-H Outfall Structure	1949-65	Reactor coolant; possible leakage and release to shoreline via concrete apron
116-H-6	183-H Solar Evaporation Basins	1973-85	Used acids from fuel fabrication activities; included chromic acid
116-H-7	107-H Retention Basin	1949-65	Temporary storage of coolant, prior to discharge into river; significant leakage created mound on underlying water table

Source: 100-H Technical Baseline Report, BHI-00127, Rev. 00, February 1995 (Deford and Einan, 1995)

Table 7-6. Hydrogeologic Units Monitored by 100-H Area Wells

Well	Screened Interval Elevation; meters/(ft)	Hydrogeologic Unit	Average Ground water Elevation meters/ (ft)
H4-12A	115.2-110.7m (378-363 ft)	Hanford fm	114.1m (374.3 ft)
H4-12B	111.6-110.1 m (366-361 ft)	Hanford fm	114.2 m (374.4 ft)
H4-12C	103.2 -100.2 m (338.6-328.6 ft)	Ringold upper mud	114.0 m (374.1 ft)
H3-2A	111.8-110.3 m (366.7-361.7 ft)	Hanford fm	114.5 m (375.7 ft)
H3-2B	114.5-111.5 m (375.6-365.6 ft)	Hanford fm	114.5 m (375.6 ft)
H4-2	14.9- 10.4 m (49-34 ft)	Ringold lower mud/ basalt	Top of casing (flowing)
H4-15A	115.2 - 110.7 m (378 - 363 ft)	Hanford fm	114.2 m (374.5 ft)
H4-12B	112.1 - 110.6 m (367.7- 362.7 ft)	Hanford fm	114.2 m (374.5 ft)
H4-15CS	99.8 - 99.2 m (327.5 - 325.5 ft)	Ringold upper mud	113.9m (373.7 ft)
HS-14CR	64.5-63.8 m (211.5-209.5 ft)	Ringold unit B	114.0 m (374.1 ft)
H4-14CQ	33.7-33.1 m (110.5-108.5 ft)	Ringold lower mud	top of casing
H4-14CP	24.5-23.9 m (80.5-78.5 ft)	basalt	flowing

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μS/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
Wells representative of conditions at or near the water table:											
199-H4-4	400	373.98	6.0	371.5	377.7	33	666	854	223	1,077	22
199-H4-10	410	374.62	4.8	372.6	377.3	18	262	140	199	339	5
199-H4-11	420	373.95	5.7	371.3	377.0	23	375	117	329	446	10
199-H4-12A	440	374.31	4.9	372.2	377.2	28	410	236	240	476	11
199-H4-12B	440	374.38	4.9	372.3	377.1	18	407	151	326	477	3
199-H4-15A	460	374.48	4.8	372.5	377.3	22	407	286	339	625	11
199-H4-15B	460	374.53	4.7	372.5	377.3	19	337	45	314	359	2
199-H4-13	500	373.63	5.9	370.8	376.7	18	306	129	244	373	6
199-H4-5	560	374.34	4.2	372.6	376.8	23	485	44	463	507	9
199-H4-18	710	374.59	2.8	373.6	376.3	22	426	194	330	524	10
199-H4-9	720	374.46	5.3	371.8	377.1	35	521	267	346	613	20
199-H4-3	730	374.53	5.5	372.4	377.8	32	1,132	992	790	1,782	20
199-H4-8	810	374.91	4.6	373.7	378.4	20	489	46	470	516	8
199-H4-17	810	374.77	3.1	373.6	376.7	21	515	42	488	530	6
199-H4-45	960	374.04	1.9	373.2	375.1	15	313	179	210	389	4
199-H4-7	1,050	375.02	2.2	374.1	376.3	19	467	191	417	608	8
199-H6-1	1,100	374.16	2.0	373.4	375.4	15	417	79	384	463	5
199-H4-16	1,120	374.94	1.7	374.2	375.9	18	308	131	277	408	5
199-H4-14	1,300	375.48	1.6	374.8	376.4	21	442	430	290	720	12
199-H4-47	1,430	375.28	1.4	374.7	376.2	15	286	196	227	423	4
199-H4-6	1,610	375.60	2.2	374.4	376.6	22	459	215	319	534	11
199-H4-48	1,610	375.52	1.5	375.0	376.5	13	260	163	209	372	4

Table 7-7. Water Level and Specific Conductance in 100-H Area Wells (Page 1 of 2)

Table 7-7. Water Level and Specific Conductance in 100-H Area Wells (Page 2 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance ($\mu\text{S}/\text{cm}$)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
199-H4-46	1,710	375.09	1.5	374.6	376.0	13	413	130	352	482	4
199-H3-2A	1,780	375.69	1.5	375.1	376.5	20	346	190	276	466	11
199-H3-2B	1,780	375.63	1.5	375.1	376.5	17	389	177	294	471	3
199-H4-49	2,110	375.96	1.1	375.5	376.6	11	383	327	243	570	4
199-H3-1	2,300	375.91	1.7	375.5	377.1	17	331	173	256	429	6
199-H5-1A	2,660	375.95	1.0	375.6	376.6	15	609	287	527	814	4
699-97-43	2,660	378.38	0.5	378.2	378.7	11	378	22	365	387	4
699-96-43	3,990	378.83	0.4	378.7	379.1	14	389	59	361	420	7
<i>Wells with open intervals significantly below the water table:</i>											
199-H4-12C	430	374.13	5.1	371.9	377.0	32	265	35	238	273	8
199-H4-15Cs	460	374.12	2.2	373.1	375.3	14					0
199-H3-2C	1,780	375.65	1.5	375.0	376.5	22	248	187	213	400	8
Notes: Wells are listed in order of increasing distance from the river shoreline, as defined by low river stage. Data are representative of conditions between January 1, 1994 and August 30, 1995. Data source: HEIS.											

Table 7-8. Aquifer Test and Drawdown Test Results for 100-H Area Wells

Well Number	Sediment Description		Screened Formation	K (ft/d) cm/sec
	Field Log	Sieve Analysis		
199-H4-45	Sandy gravel	Gravelly sand	Hanford	(100) 0.0353
199-H4-46	Sandy gravel/gravelly sand	Gravelly sand	Hanford	(120) 0.0423
199-H4-47	Silty sandy gravel	Sandy gravel	Hanford	(90) 0.0318
199-H4-48	Sandy gravel/gravelly sand	Slightly gravelly sand	Hanford	(80) 0.0282
199-H4-49	Sandy gravel	Slightly sandy gravel	Hanford	(90) 0.0318
199-H5-1	Sandy gravel/sand	Sand	Hanford	(110) 0.0388
199-H6-1	Sandy gravel	NA	Hanford	(70) 0.0247
699-96-43	Gravelly sand/silty clay	Silty sand	Hanford	(50) 0.0176

cm/sec = centimeters per second

ft/d = feet per day

K = hydraulic conductivity

NA = not available

Sources: Drawdown test data from DOE-RL (1995j). Slug test data from DOE-RL (1994c).

Table 7-9. Physical Properties for Aquifer Sediments in the 100-H Area

Well Number/ Depth Interval m (ft)	Designation	Specific Gravity g/cm ³	Bulk Density gm/cm ³	Moisture Content %	K, Saturated cm/sec	Depth-to- Water m (ft)	Sediment Description
H4-46; 17.38- 17.68m, (57-58 ft)	NA	NA	NA	NA	7.9 E-04	14.04m (46.04 ft)	Gravelly SAND
H4-46; 10.82-11.13 m, (35.5-35.5 ft)	B05X40	Not available	Not available	Not available	2.4 E-02	14.04 m (46.04 ft)	Gravelly SAND
H4-46; 6.58-6.74 m, (21.6-22.1 ft)	B05X39	Not available	Not available	Not available	1.6 E-03	14.04 m (46.04 ft)	Sandy GRAVEL
H4-45; 10.21-10.52 m, (33.5-34.5 ft)	B05X37	2.77	2.08	9.7	7.3 E-05	12.12 m (39.74 ft)	Gravelly silty SAND
H4-45; 7.77-8.08 m (25.5-26.5 ft)	B05X36	2.73	2.10	5.4	2.6 E-05	12.12 m (39.74 ft)	Silty sandy GRAVEL
H4-45; 14.79-15.09 m (48.5-49.5 ft)	B05X38	Not available	Not available	Not available	1.2 E-03	12.12 m (39.74 ft)	Sandy GRAVEL
H5-1; 5.34-5.64 m (17.5-18.5 ft)	B05X52	2.66	2.2	4.6	2.3 E-03	12.53 m (41.1 ft)	Silty sandy GRAVEL
H5-1; 9.45-9.60 m (31.0-31.5 ft)	B05X53	Not available	Not available	Not available	8.1 E-04	12.12 m (41.1 ft)	Sandy GRAVEL
H5-1; 15.4-15.7 m (50.5-51.5 ft)	B05X54	2.8	2.28	3.2	Not available	12.12 m (41.1 ft)	Silty gravelly SAND

8.0 100-FR-3 OPERABLE UNIT

The 100-FR-3 Operable Unit Contains the groundwater underlying the 100-F Area. It also includes adjacent areas where contaminated groundwater from the 100-F Area may pose a risk to human and ecological receptors. Examples of adjacent areas are the riverbed, where groundwater may upwell into sediments that form habitat for aquatic life, and locations where water seeps from the riverbank during low river conditions. Figure 8-1 is an index map for the 100-F Area that shows the locations of groundwater monitoring wells and facilities/waste sites discussed in the text.

The following sections describe contaminants of concern, their distribution, how they change with time, and the hydrogeologic framework through which they move. The operable Unit Conceptual site model (CSM) description ends with a summary of uncertainties in the CSM.

8.1 CONTAMINANTS OF CONCERN

Contaminants of concern may be chemical or radiological constituents that pose a risk to human and/or ecological receptors. Numerous regulatory requirements, such as the U.S. Environmental Protection Agency's (EPA) drinking water standards (40 CFR 141 "maximum contaminant levels" [MCL]) and ambient water quality criteria (AWQC) for protection of freshwater aquatic organisms, help identify which constituents are of concern.

A limited field investigation (LFI) for the 100-FR-3 Operable Unit identified contaminants of potential concern based on a limited set of data collected in 1992 and 1993. These contaminants were used in a qualitative risk assessment, the results of which included recommendations regarding interim remedial measures (IRM). The contaminants of concern, conclusions, and recommendations contained in the LFI report (DOE-RL, 1994d) are as follows:

Operable Unit	Human Health Risk	Ecological Risk	LFI Conclusion and Recommendation
100-FR-3	Arsenic Chromium Manganese Nitrate Strontium-90 Tritium	Chromium Copper Lead	An IRM is not indicated by human health or ecological risk. Continue on IRM pathway; continue RI/FS process. Trichloroethene, while not a risk driver, exceeds a potential applicable or relevant and appropriate requirement (ARAR).

Sourced: Limited Field Investigation Report (DOE-RL, 1994v) and Soil Gas Supplemental Limited Field Investigation Report (DOE-RL, 1995m)

These contaminants of concern continue to be tracked primarily by semiannual sampling of wells since the LFI phase of the remedial investigation/feasibility study (RI/FS). As sufficient information becomes available to demonstrate that a contaminant is no longer of concern with respect to human health and ecological risk, it is typically removed from the monitoring schedule. However, data for some discontinued contaminants of concern may continue to accumulate because the constituent is part of a grouped analysis (e.g., analysis of metals by inductively coupled plasma [ICP]).

8.1.1 Summary of Current Groundwater Contamination Levels

Table 8-1 presents recently observed concentrations for contaminants of potential concern identified during the LFI, as well as concentrations for additional waste and water quality indicators. This table includes all results contained in the Hanford Environmental Information System (HEIS) database for sampling more recent than January 1, 1995 (generally inclusive of sampling conducted through January 1996). Semiannual sampling has been the norm since the last half of 1994, so this summary is predominantly based on two or three sampling events per well.

Initial data evaluation processing has been completed on the entire data set summarized in Table 8-1 (i.e., assigning common units, removing duplicate entries, and correcting known errors in reported results). The full data evaluation process has been completed for chromium, nitrate, strontium-90, tritium, and specific conductance (see Ford and Denslow, 1996 for a description of the data evaluation process for data extracted from HEIS). Some values in Table 8-1 for constituents other than the five listed above may be less representative of aquifer conditions than values for fully evaluated constituents.

The list of constituents that currently exceed regulatory standards is similar to the list of contaminants of potential concern identified during the LFI. Aluminum, chromium, manganese, nitrate, and iron are elevated in several wells and are of potential concern. Arsenic, copper, and lead no longer exceed standards in 100-F Area wells. Strontium-90 (and gross beta activity), gross alpha, and tritium remain elevated in several wells. Trichloroethene (TCE) remains above standards in two wells, as in the past. Table 8-2 identifies the 100-F Area wells in which various constituents included in Table 8-1 exceed standards.

8.1.2 Sources for Contamination in Groundwater

The principal surface facilities associated with liquid waste disposal to the soil column are shown in Figure 8-1. A detailed description of these waste-generating facilities is contained in the "100-F Area Technical Baseline Report" (Deford, 1993). A description of how the plutonium production reactors operated is presented in the "Hazards Summary Report" for the production reactor plants (General Electric, 1963). Both documents provide comprehensive background material for interpreting the origin of groundwater contamination. The source information contained in the following summary is derived from those documents, unless otherwise cited.

The greatest volumes of liquid waste were associated with the retention basin and effluent pipelines that lead to the basin from the 105-F Reactor building. This basin received reactor coolant effluent, which typically contained radionuclides and hexavalent chromium. Significant leakage of this effluent occurred from the retention basin. Although short-lived radionuclides in the leakage decayed away quickly, longer-lived radionuclides were retained by sediments in the soil column. Hexavalent chromium moved unimpeded downward through the soil column and into the underlying groundwater.

Approximately 1 million cubic ft (7.5 million gal) per day of coolant was estimated to have entered the soil column from the retention basin (Brown, 1963). Sodium dichromate was added to coolant makeup water to form a solution of 2 mg/L sodium dichromate. The sodium dichromate dissociated to create a 700 $\mu\text{g/L}$ (maximum) concentration of hexavalent chromium. At this concentration, the leakage of used coolant would have introduced slightly less than 20 kg per day of hexavalent chromium to the soil column, which was subsequently dispersed by groundwater flow.

The leakage of coolant effluent from the retention basin was sufficient to create a mound on the natural water table, thus altering the normal pattern for groundwater flow through the 100-F Area. Some groundwater containing contamination may have been driven upgradient (inland) by the mounding, to later return under the influence of the natural water table gradient. The inland extent of this "reverse" flow was probably limited, however, since the aquifer immediately west of the retention basin is relatively thin (see Figure 8-9).

Contamination driven inland from the retention basin would have encountered a buried former river channel that runs roughly north and south through the 100-F Area. At certain times of the year, river water recharges the aquifer via this channel, with movement toward the south (Brown, 1963). The nitrate plume extending south and east from the 100-F Area (see Figure 2-1) provides evidence for this buried channel acting as a contaminant dispersal pathway.

A liquid waste disposal trench, which is located near the retention basin and Columbia River, received highly contaminated coolant water that resulted when a fuel element ruptured. Reactor coolant effluent was diverted to the trench for soil column disposal. This procedure allowed more time for short-lived radionuclides to decay prior to entering the river and allowed the soil column to absorb and retain the long-lived radionuclides. Residual groundwater contamination associated with these trenches is expected to be predominantly radionuclides (e.g., strontium-90). A second liquid waste trench is also located near the retention basin; it received liquid wastes from cleaning associated with the experimental animal laboratories. Nitrate and radionuclide contamination in groundwater may be attributed to this trench.

Other prominent liquid waste disposal sites include small cribs and French drains near the reactor buildings. These facilities were typically used to dispose of decontamination solutions, including nitric and chromic acids, that contained metals and radionuclides. Each reactor also had a "fuel storage basin percolation pit," which was used to dispose of once-through coolant water for the fuel storage basins. These facilities were a source for tritium and other radionuclides.

As part of source operable unit investigations, summaries of waste sites have been prepared that list known waste sites, describe their characteristics, and indicate the contaminants of concern associated with each site. These summaries were originally presented in the proposed plans for the 100-FR-1 and 100-FR-2 Operable Units (DOE-RL, 1995n and DOE-RL, 1995o). They are included here as Tables 8-3 and 8-4.

8.2 CONTAMINANT DISTRIBUTION MAPS AND TREND CHARTS

Chromium, strontium-90, and nitrate concentrations for data obtained since January 1, 1995 have been plotted on maps to illustrate the current distribution of contamination in 100-F Area groundwater. The maps include water table contours for long-term average elevations (January 1, 1994 through August 30, 1995). Groundwater flow is generally oriented perpendicular to the contour lines. TCE contamination is described, using trend charts.

The concentrations plotted are average values for data from HEIS that have undergone the full data evaluation process (Ford and Denslow, 1996). This process is intended to produce concentration values that accurately represent aquifer conditions. The average values presented do not include results considered nonrepresentative ("outliers") by the data evaluator. Chromium results are for filtered samples, since these data provide the best indicator of chromium dispersed by groundwater flow.

Chromium concentrations are shown in Figure 8-2. A widespread plume of chromium contamination is not present in the 100-F Area, and concentrations in near-river wells are near detection levels and below AWQC ($11 \mu\text{g/L}$). A hot spot is present near well 199-F5-46, although a source for this elevated concentration is not obvious. Concentration trends for this well and nearby upgradient wells are shown in Figure 8-3. The wide variation in chromium concentrations in well 199-F5-46 may be associated with complex groundwater movement caused by buried former river channels, which act as preferential pathways. Groundwater flow is influenced by river discharge conditions and seasonal water table changes.

Strontium-90 is elevated in the area around the retention basin and liquid waste disposal trench (Figure 8-4). The highest average value (135 pCi/L in 199-F5-3) appears to be residual contamination associated with the trench. Concentration trend charts for this well and adjacent wells are shown in Figure 8-5.

Nitrate concentrations are shown in Figure 8-6. Nitrate provides a good indication of contaminant movement through preferential pathways created by buried former river channels. Movement is generally to the south and southeast from sources near the 105-F Reactor building and the Lewis Canal. Nitrate trends for selected wells are shown in Figure 8-7, and include well 199-F5-45, which has shown a distinct upward trend in recent years, the cause for which is uncertain.

TCE is elevated in two wells in the southwest corner of the 100-F Area (wells 199-F7-1 and 699-77-36). Trend charts for these wells are shown in Figure 8-8. The source for TCE is

presumed to be to the west and northwest of these wells, and not associated with 100-F Area operations (DOE-RL, 1995m).

8.3 HYDROGEOLOGY

This section describes the framework through which contamination may be transported by groundwater movement. The lithologies of the stratigraphic units, the saturated and unsaturated zones, and physical properties of the various hydrostratigraphic units are described in the following sections.

8.3.1 Hanford and Ringold Stratigraphic Units

The most important stratigraphic units underlying the 100-FR-3 groundwater operable unit are the Hanford formation (informal nomenclature) and the Ringold Formation. Figure 8-9 shows a geologic cross section oriented perpendicular to the Columbia River channel. Figure 8-10 shows a cross section oriented approximately parallel to the Columbia River (see Figure 8-1 for the locations of the cross sections). These cross sections show the Hanford-Ringold contact, graphically display sediments recovered during drilling of the groundwater monitoring wells, and show the range in depth to groundwater during the period from January 1, 1994, to August 30, 1995. A more detailed description of the geologic section down to the top of basalt is presented in Raidl (1994).

8.3.1.1 Hanford formation. The Hanford formation in the 100-F Area is dominated by sandy gravel and silty sandy gravel beds, with local sand or silt interbeds (see Figures 8-9 and 8-10). The thickness of the Hanford formation ranges from about 8 m (25 ft) in well 199-F7-1 in the western part of 100-FR-3 to about 24 m (80 ft) in well 199-F5-2 near the Columbia River. The contact between the Hanford formation and the underlying Ringold Formation was selected as the top of the first silt- or clay-dominated stratum under the Hanford formation gravels. The contact varies in elevation from well to well.

8.3.1.2 Ringold Formation. The upper Ringold Formation in the 100-F Area is dominated by silt and sandy silt, with sandy interbeds. This unit is commonly referred to as the Ringold "upper mud." A maximum of 58.5 m (192 ft) of Ringold Formation was penetrated by well 199-F5-43B.

8.3.2 Vadose Zone and Uppermost Aquifer

The vadose zone ranges in thickness from 5.8 m (18.9 ft) in well 199-F7-1 in the western part of the area to 14.0 m (46 ft) in well 199-F5-47, south of the 105-F Reactor building. Figures 8-9 and 8-10 show the top of the saturated zone (water table) is located in the lower Hanford formation. The uppermost aquifer is also limited to the Hanford formation because, in the 100-F Area, the upper Ringold is an aquiclude. The maximum saturated thickness of the Hanford formation is about 9.1 m (30 ft) in well 199-F5-2.

Geologic sections A-A' and B-B' (Figures 8-9 and 8-10) show maximum and minimum groundwater elevations from January 1, 1994, to August 30, 1995, as measured in wells along the geologic sections. Wells near the Columbia River (199-F5-44) vary up to 2.13 m (6.98 ft) in groundwater elevation, while wells inland (199-F7-1) vary as little as 0.08 m (0.27 ft) in groundwater elevation. The range in groundwater elevation in wells near the river is largely due to the effect of river stage change.

The contaminant plume maps presented earlier (see Figures 8-2, 8-4, and 8-6) show the elevation of the water table using average elevations from January 1, 1994, to August 30, 1995. The flow direction in the northern part of the 100-F Area is to the east-northeast and swings to the southeast in the southern part of the site. The approximate water table gradient is 0.0013.

The presence of a distinct upward hydraulic gradient has not been confirmed in the 100-F Area. Figure 8-11 shows hydrographs of hourly data for paired wells 199-F5-43A and -43B, which are located near the river. Well 199-F5-43A is screened from elevation 107.4 to 113.5 m (352.3 to 372.3 ft) in Hanford formation gravelly sand, and 199-F5-43B is screened at elevation 72.2 to 75.2 m (236.7 to 246.7 ft) in a producing horizon within the Ringold Formation overbank deposits. Both wells appear to respond to river stage fluctuations with similar patterns. No 100-F Area wells provide data from deeper horizons in the area, so the characteristics of vertical gradients remain uncertain.

The average groundwater elevation indicated by periodic steel tape measurements also are inconclusive (Table 8-5). The long-term average elevation in 199-F5-F43B (the deeper well) is 0.055 m (0.18 ft) lower than the average elevation in 199-F5-43A (the shallower well), although the range in groundwater elevations is similar for both wells. This suggests that changes in river stage elevation affect 199-F5-43B similarly to the adjacent 199-F5-43A.

8.3.3 River Influence on Monitoring Wells

Water level elevations and specific conductance are used to qualitatively evaluate the influence the river has on monitoring wells. Table 8-6 summarizes water level elevations and specific conductance for each 100-F Area well, and shows the well's distance inland from the river's low-water shoreline. The wells are separated into two groups in the table: (1) those that have screened or perforated open intervals that include the water table and (2) those that are open at depths in the aquifer well below the water table.

Data for Table 8-6 were extracted from HEIS in the form of depth-to-water measurements. These values were combined with recent top-of-casing surveys, using either results from an extensive 1993 U.S. Army Corps of Engineers survey, or, when Corps data are not available, results from a recent ICF Kaiser Hanford, Inc., survey. These surveys are referenced to baseline monuments, the locations of which were re-established by the Corps in 1993. All data are referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

The average water level elevation is from data obtained during the period from January 1, 1994, through August 30, 1995. This average represents long-term conditions over slightly more than

a seasonal cycle. The range between minimum and maximum water level elevations provides a measure of the degree to which river stage fluctuations influence the well. The range is also influenced by the degree to which the aquifer segment intercepted by the well is confined. In response to river fluctuations, more confined segments produce greater changes in well water levels.

Values for specific conductance are also included in Table 8-6. Specific conductance, which varies with the amount of dissolved salts in the groundwater, can be used to identify water of various origins. River water is typically in the range of 120 to 140 $\mu\text{S}/\text{cm}$. Groundwater from the Hanford gravels is approximately 400 $\mu\text{S}/\text{cm}$, while water from the Ringold Formation appears to be approximately 300 $\mu\text{S}/\text{cm}$, although data to support the latter are limited. Given these contrasts, specific conductance is useful in helping to describe the interaction between river water and groundwater. However, where contamination is present, specific conductance may vary over a wide range, thus reducing its usefulness as a mixing indicator for natural waters.

8.3.4 Aquifer Properties

Slug tests were conducted in 12 wells at 100-F Area that were constructed during the LFI. The results were analyzed in accordance with Bouwer and Rice (1976) and Bouwer (1989). Hydraulic conductivities ranged from 0.011 to 0.79 cm/s (30 to 225 ft/d). Table 8-7 is a summary of the conductivities calculated from the data (Raidl, 1994).

8.3.5 Physical Properties of Aquifer Materials

Table 8-8 is a summary of physical-properties testing conducted on 12 samples collected from wells 199-F8-3, 199-F5-48, and 199-F5-43B. Particle size, specific gravity, bulk density, moisture content, and saturated hydraulic conductivity were determined for each sample. Samples were collected in each well from the top and bottom halves and from below the water table. The sampling was biased toward finer sediments because they were easier to collect than large gravels or cobbles. The sample description is based on the particle size distribution of the sample. Water level data is included to clarify whether the sample was collected from the saturated zone in the well.

Figure 8-1. Wells and Principal Surface Facilities - 100-FR-3 Operable Unit

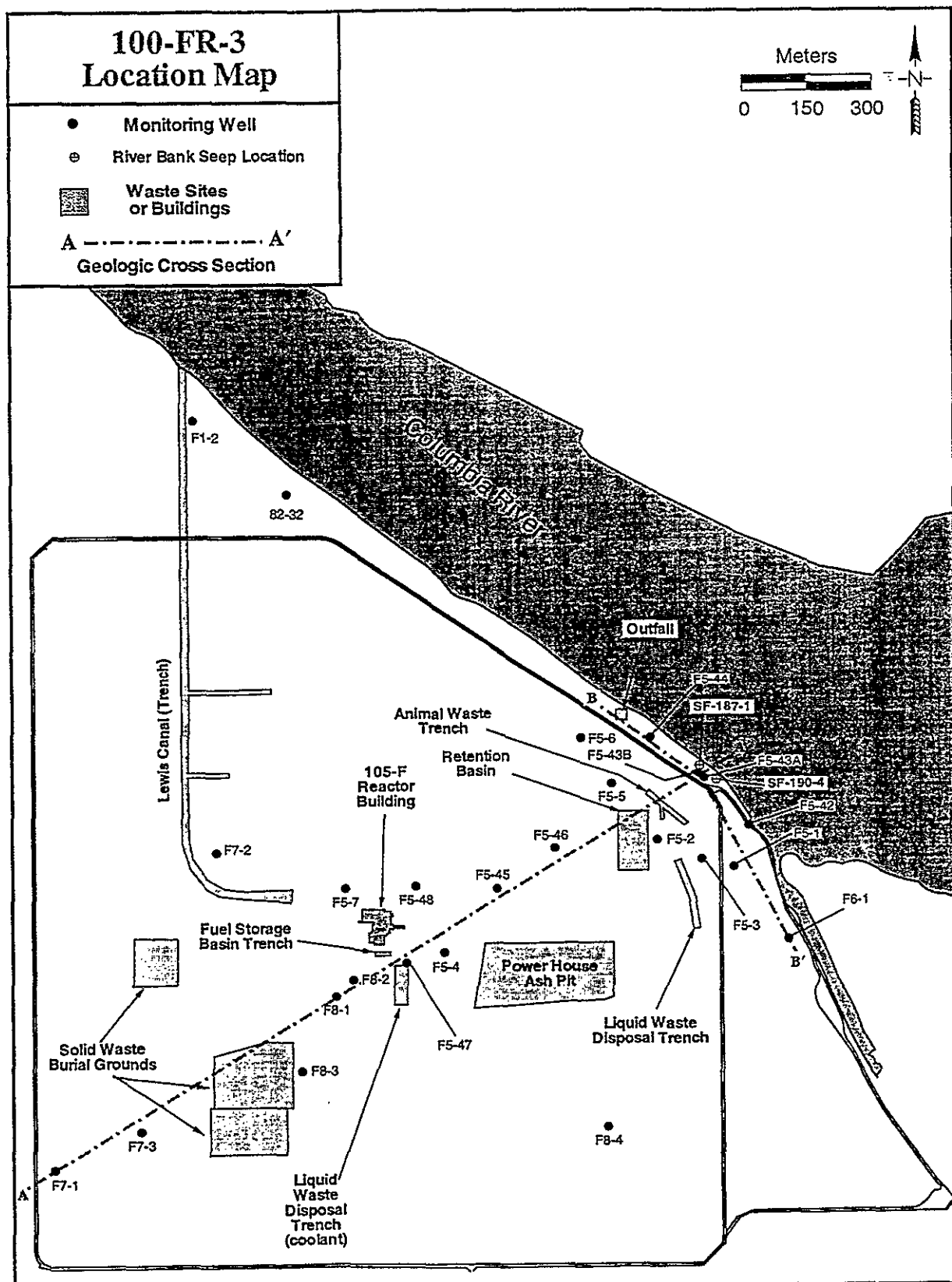


Figure 8-2. Chromium Distribution in the 100-F Area

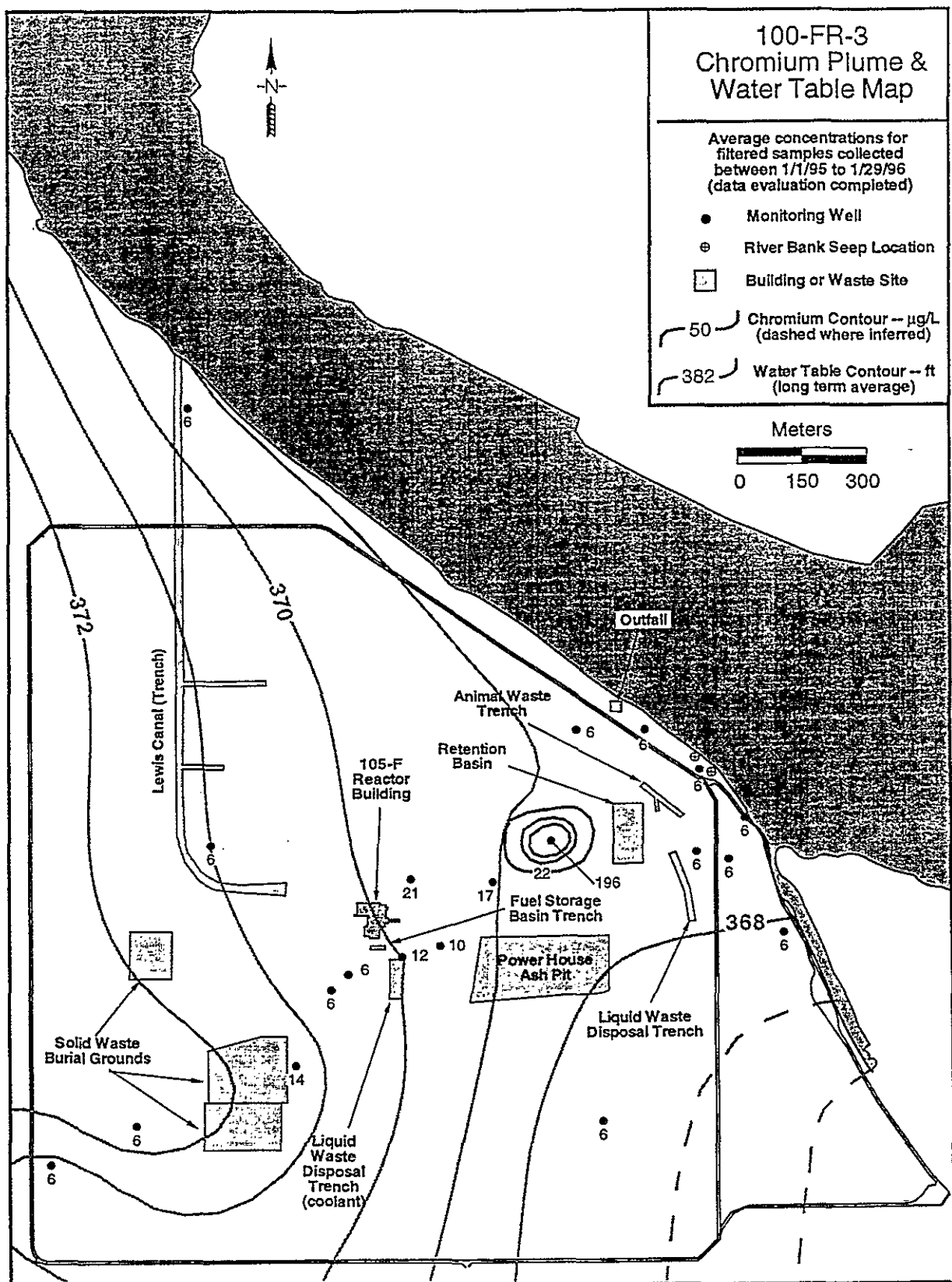


Figure 8-3. Chromium Trends in Selected 100-F Area Wells

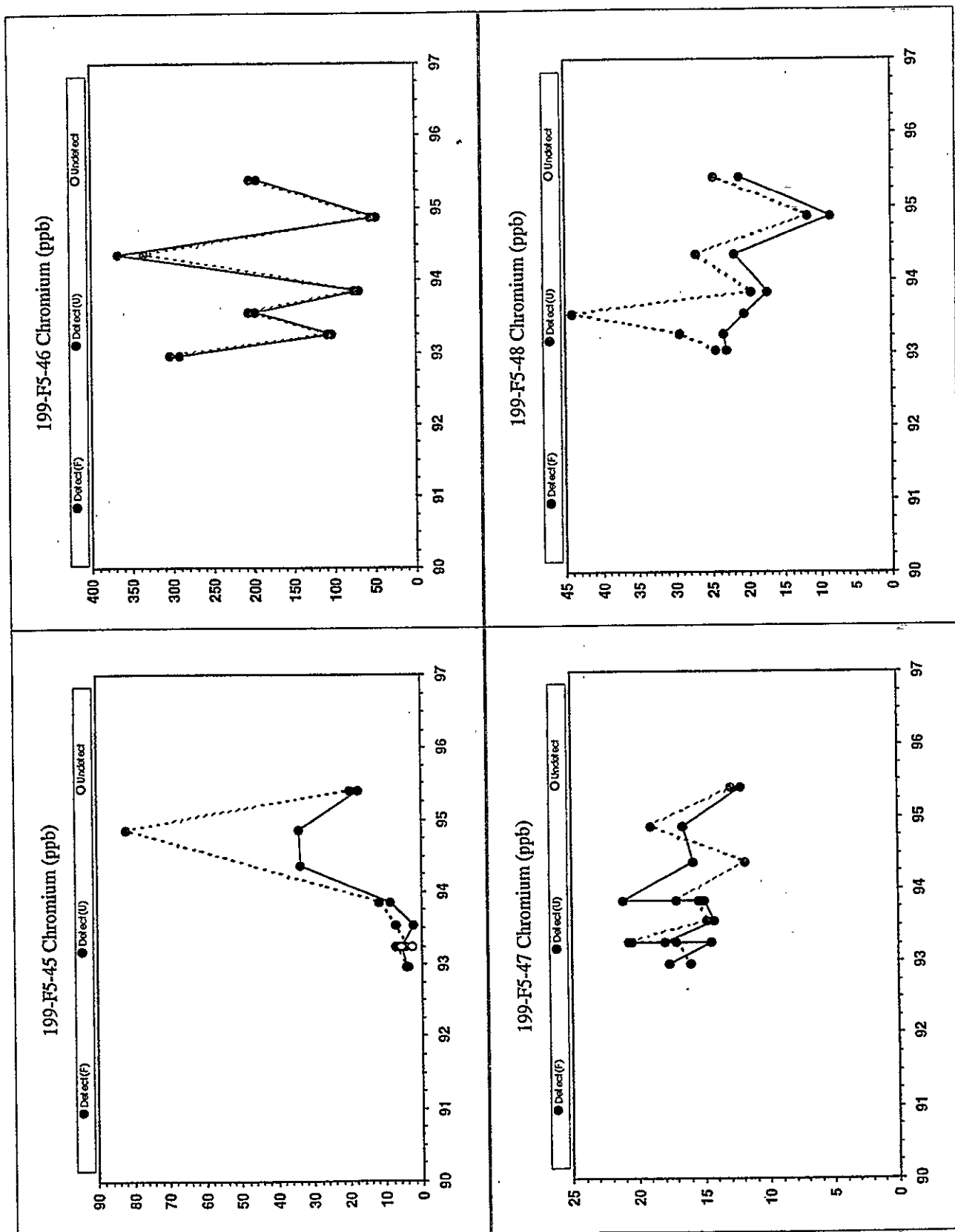


Figure 8-4. Strontium-90 Distribution in the 100-F Area

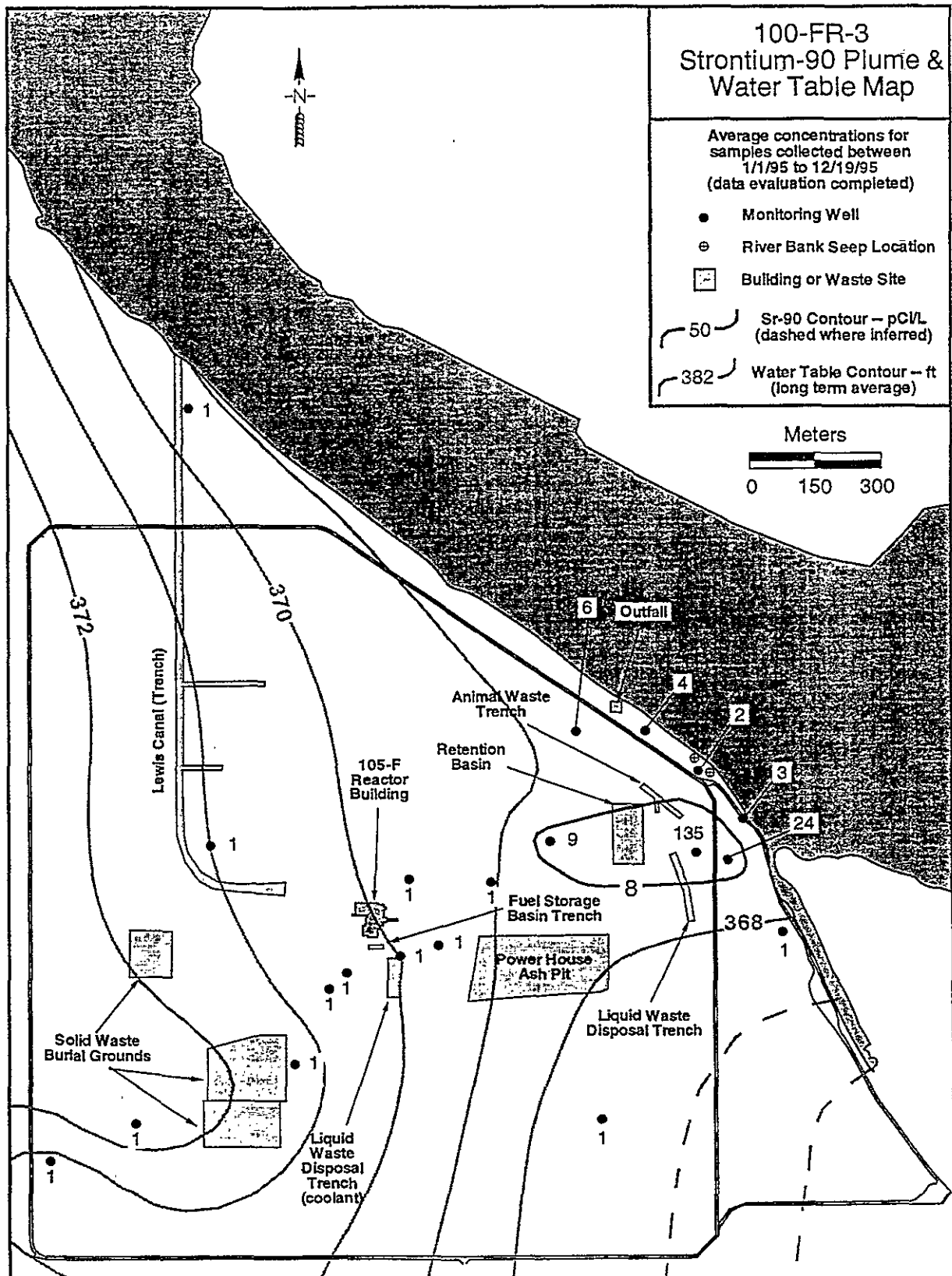


Figure 8-5. Strontium-90 Trends in Selected 100-F Area Wells

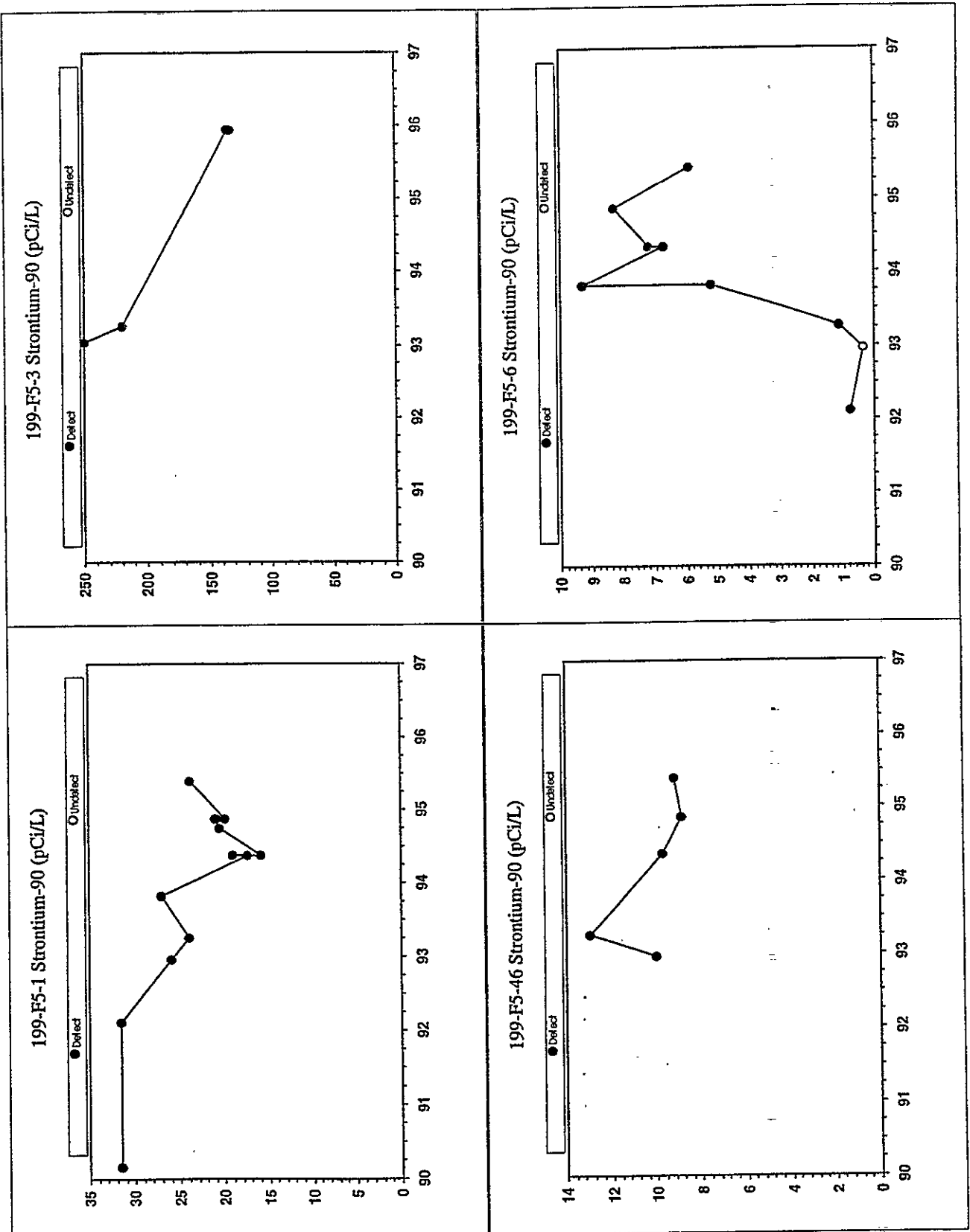


Figure 8-6. Nitrate Distribution in Selected 100-F Area Wells

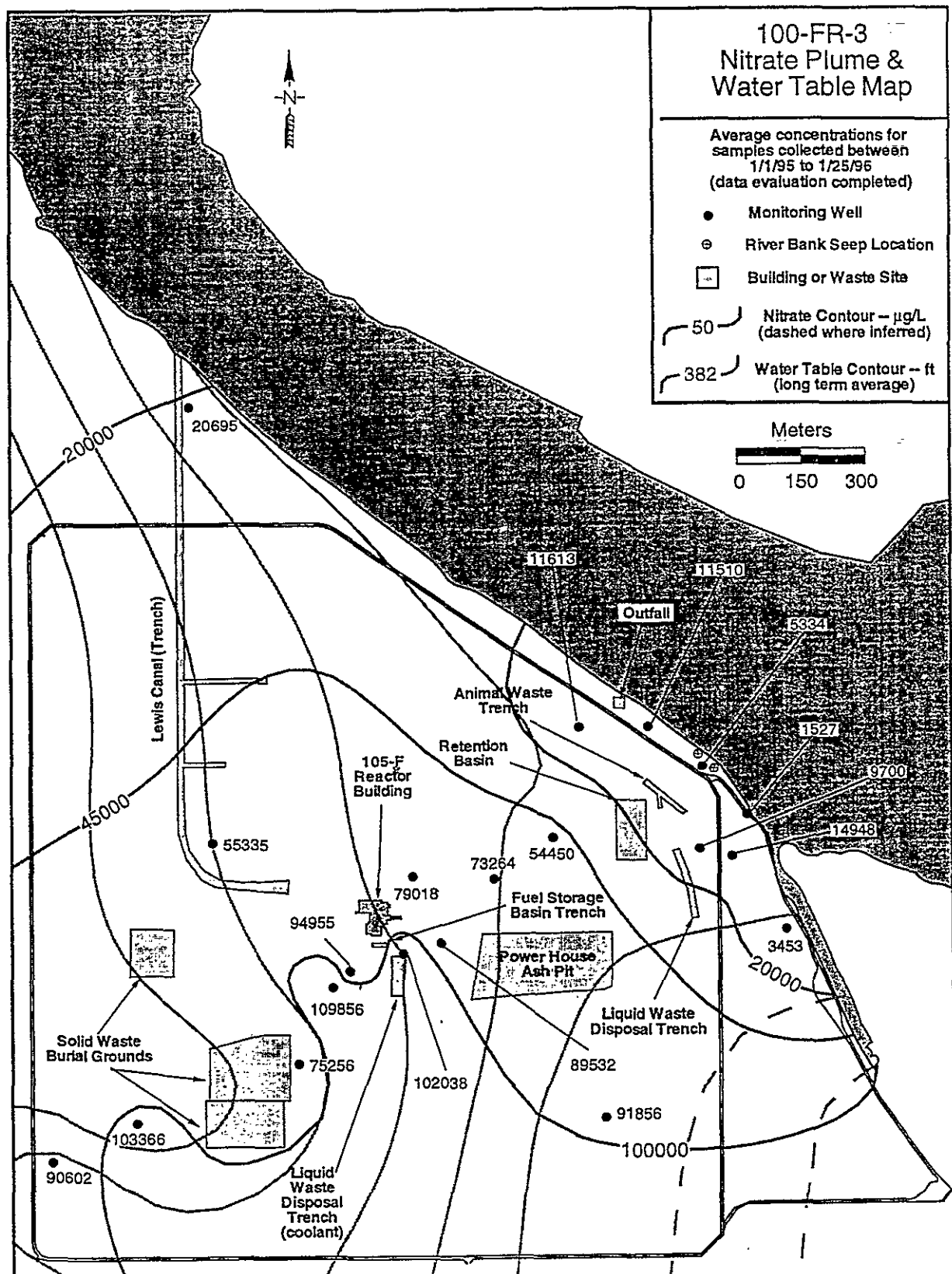


Figure 8-7. Nitrate Trends in Selected 100-F Area Wells

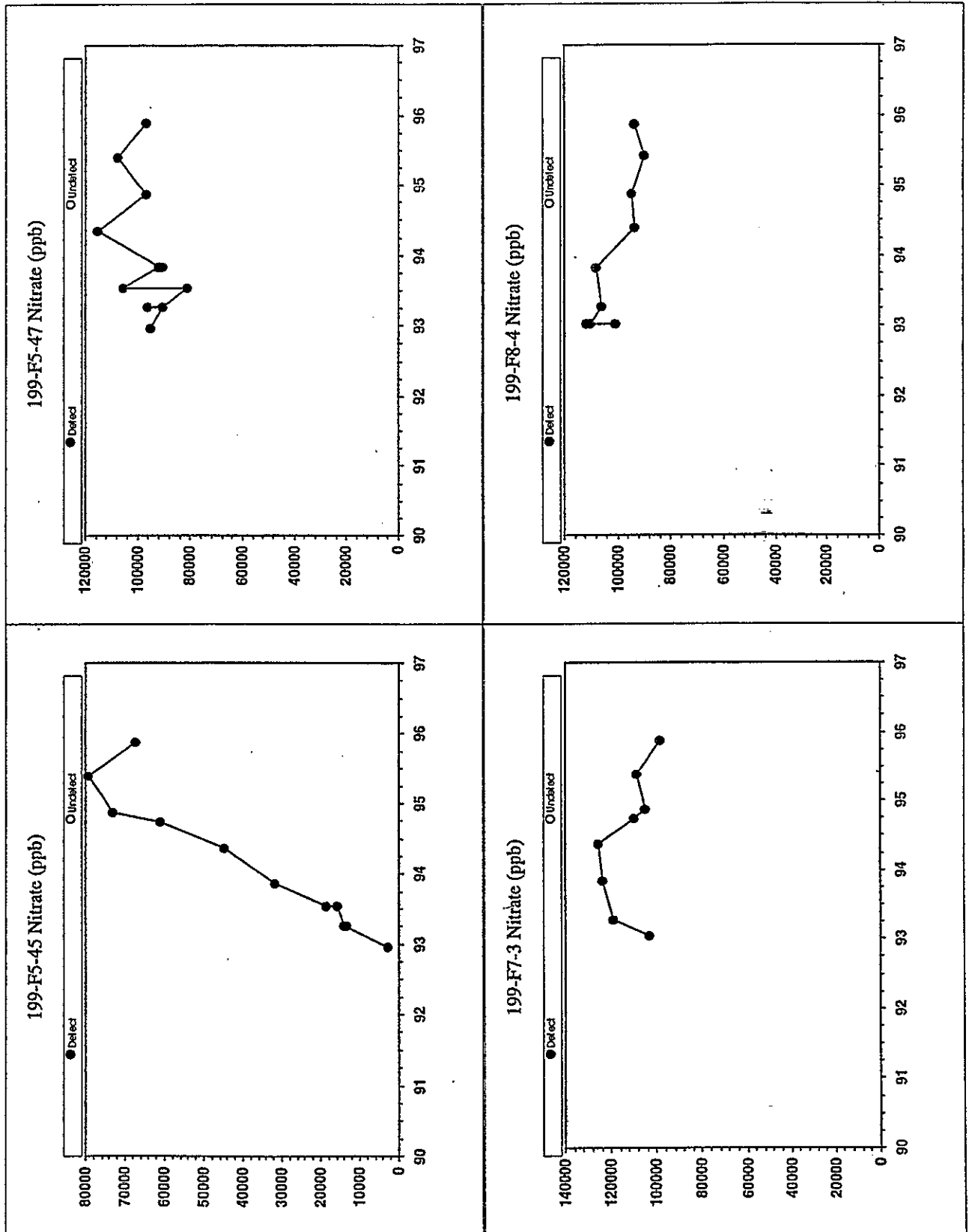
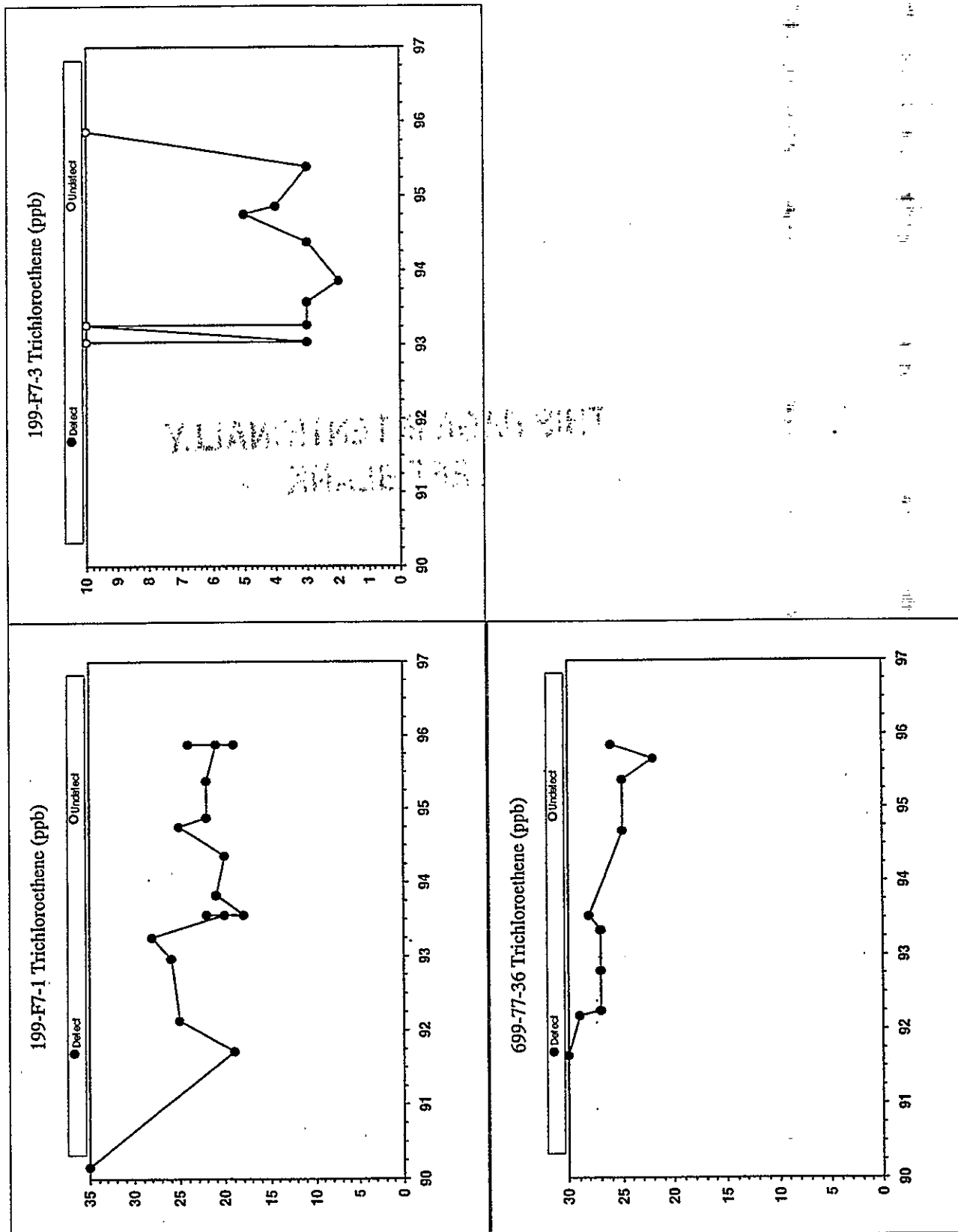


Figure 8-8. Trichloroethene (TCE) Trends in Selected 100-F Area Wells



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Figure 8-9. Cross Section (A-A') Perpendicular to the 100-F Area Shoreline

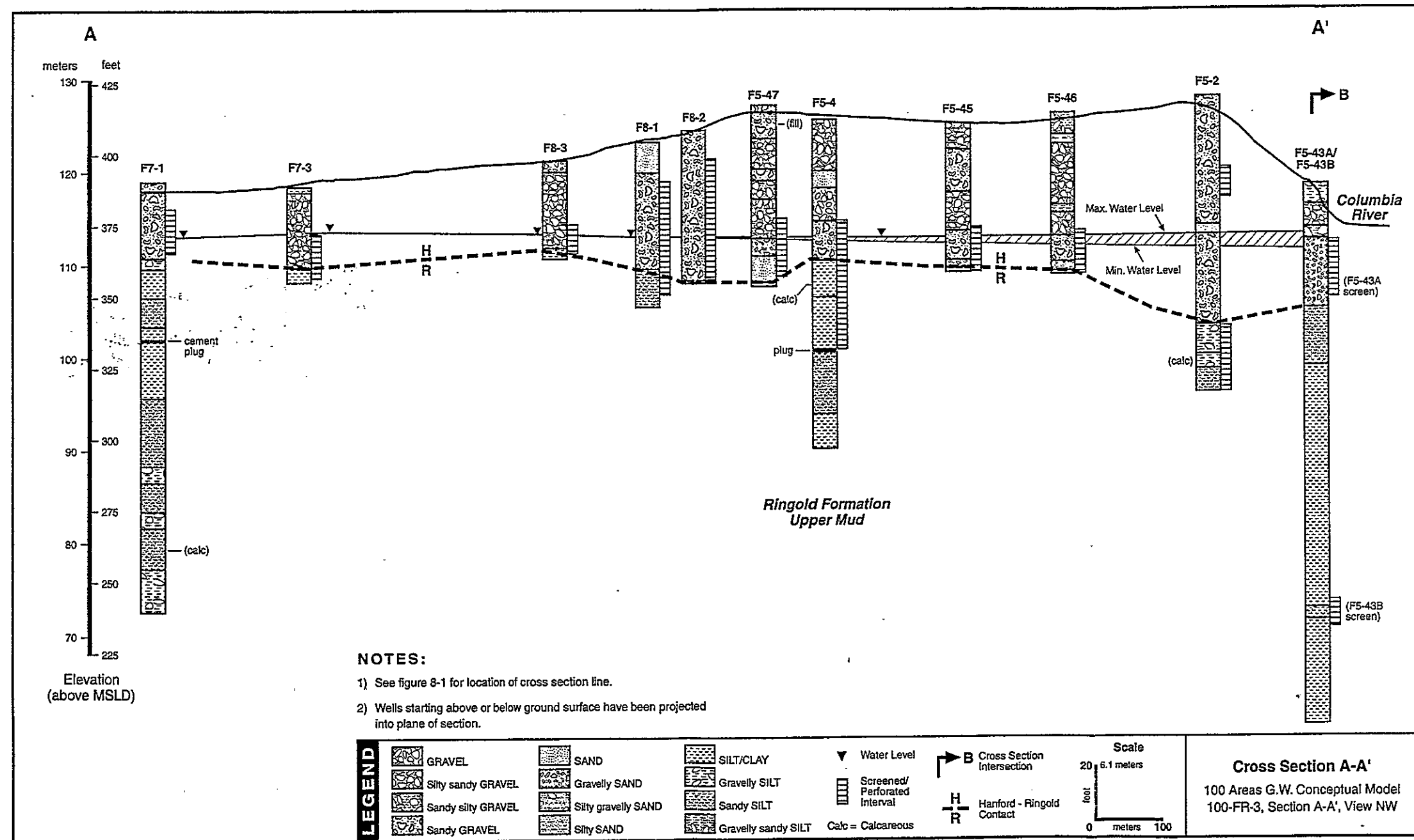


Figure 8-10. Cross Section (B-B') Parallel to the 100-F Area Shoreline

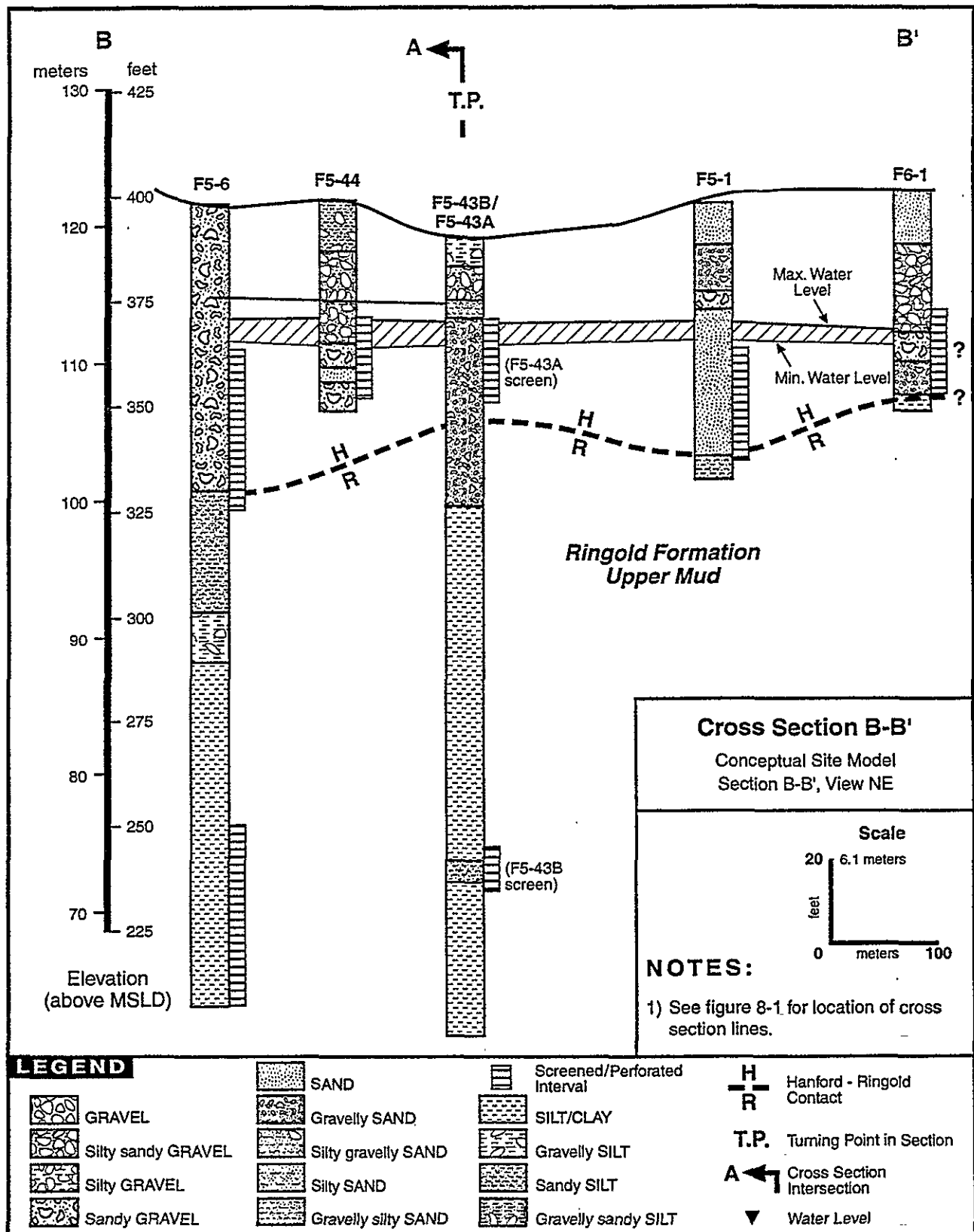
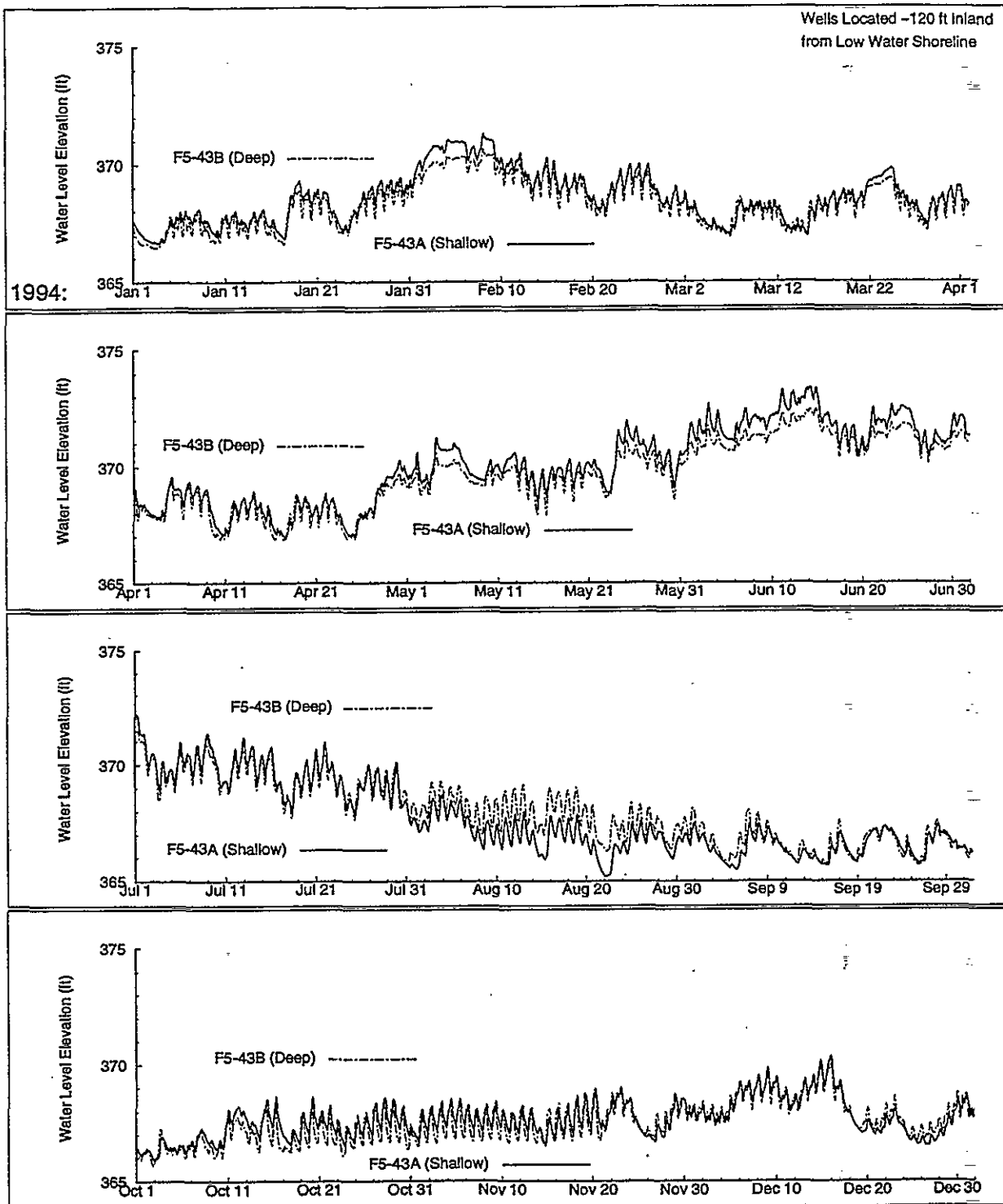


Figure 8-11. Hydrographs for Shallow and Deep Wells in the 100-F Area



100-FR-3 Chemical Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
1,1,1-Trichloroethane	ppb	N	22	55	0	0.00	0.00	0.00	200	MCL	0	0	
Aluminum	ppb	N	22	56	8	24.90	251.00	85.43	50	SMCL	3	0	
Aluminum	ppb	Y	23	49	4	26.30	44.80	35.03	50	SMCL	0	0	6.86
Arsenic	ppb	N	21	55	45	0.82	12.50	4.74	50	MCL	0	0	
Arsenic	ppb	Y	21	45	38	1.20	11.10	5.01	50	MCL	0	0	8.06
Barium	ppb	N	22	56	56	18.90	138.00	47.73	1000	MCL	0	0	
Barium	ppb	Y	23	49	49	16.00	138.00	48.90	1000	MCL	0	0	91.57
Cadmium	ppb	N	22	56	2	2.80	5.00	3.90	10	MCL	0	0	
Cadmium	ppb	Y	23	49	5	1.20	4.60	2.56	10	MCL	0	0	3.07
Chloride	ppb	N	23	55	55	840.00	38500.00	12441.09	250000	SMCL	0	0	16863.99
Chromium	ppb	N	22	56	38	3.90	204.00	21.35	50	MCL	2	0	
Chromium	ppb	Y	23	49	32	4.00	196.00	20.33	50	MCL	2	1	16.61
Copper	ppb	N	22	56	15	7.50	44.60	15.22	1300	MCL-P	0	0	
Copper	ppb	Y	23	49	19	2.90	19.80	11.41	1300	MCL-P	0	0	0.85
Fluoride	ppb	N	23	55	49	73.00	1100.00	354.73	1400	MCL	0	0	904.00
Iron	ppb	N	22	56	22	34.40	21000.00	1028.43	300	SMCL	1	0	
Iron	ppb	Y	23	49	12	20.00	165.00	62.38	300	SMCL	0	0	415.86
Lead	ppb	N	21	55	1	0.95	0.95	0.95	50	MCL	0	0	
Lead	ppb	Y	21	45	2	0.81	0.82	0.81	50	MCL	0	0	3.47
Manganese	ppb	N	22	56	32	2.70	860.00	47.55	50	SMCL	3	0	
Manganese	ppb	Y	23	49	30	0.72	232.00	19.21	50	SMCL	2	1	40.11
Nickel	ppb	N	22	56	0	0.00	0.00	0.00	100	MCL	0	0	
Nickel	ppb	Y	23	49	2	12.70	19.00	15.85	100	MCL	0	0	2.19
Nitrate	ppb	N	23	52	52	208.06	115539.48	56723.15	45000	MCL	31	12	31725.97
Selenium	ppb	N	2	3	1	4.80	4.80	4.80	10	MCL	0	0	
Selenium	ppb	Y	1	1	1	6.70	6.70	6.70	10	MCL	0	0	6.01
Silver	ppb	N	22	56	2	4.00	4.20	4.10	50	MCL	0	0	
Silver	ppb	Y	23	49	1	6.50	6.50	6.50	50	MCL	0	0	5.68
Sulfate	ppb	N	23	55	55	9250.00	152000.00	52108.18	250000	SMCL	0	0	84676.12
Trichloroethene	ppb	N	22	55	17	0.28	26.00	13.19	5	MCL	9	2	
Uranium	ppb	N	4	4	4	3.69	257.01	70.93	44	UMTR	1	1	9.28
Zinc	ppb	N	22	56	29	3.20	3000.00	160.16	5000	SMCL	0	0	21.47
Zinc	ppb	Y	23	49	24	4.30	138.00	27.81	5000	SMCL	0	0	21.47

Table 8-1. Constituents Summary for 100-FR-3 Operable Unit (Page 1 of 2)

100-FR-3 General Properties

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Dissolved Oxygen	mg/L	N	21	42	42	1.20	8.60	5.55			0	0	14935.41
pH Measurement	pH	N	24	52	52	4.88	9.96	7.56			0	0	8.07
Specific Conductance	umhos/cm	N	24	43	43	188.00	1102.00	592.00			0	0	428.00
Temperature	Deg C	N	24	52	52	13.60	29.10	18.19			0	0	

100-FR-3 Radiological Constituents

Constituent	Units	Filtered	# of Wells Sampled	# of Results	# of Detects	Min	Max	Avg	Standard	Type	# of Samples Exceeding Standard	# of Wells Exceeding Standard	Background Value
Carbon-14	pCi/L	N	21	52	21	4.30	341.00	44.33	2000	MCL	0	0	152.79
Gross Alpha	pCi/L	N	21	50	42	0.83	206.00	14.33	15	MCL	3	2	2.47
Gross Beta	pCi/L	N	21	50	50	3.13	98.20	16.99	50	MCL	5	2	7.44
Strontium-89/90	pCi/L	N	21	27	10	1.03	24.90	10.76			0	0	0.02
Strontium-90	pCi/L	N	22	25	10	0.94	135.84	32.03	8	MCL	4	3	0.02
Technetium-99	pCi/L	N	1	1	1	0.00	0.00	0.00	900	MCL	0	0	1.78
Tritium	pCi/L	N	23	58	41	0.00	111000.00	8199.83	20000	MCL	2	1	162.00

Data Source: Hanford Environmental Information System. Abbreviations: MCL = EPA maximum contaminant level (primary); MCL-P = EPA maximum contaminant level (proposed); SMCL = EPA maximum contaminant level (secondary); EPA 440/5-86-001-USEPA Freshwater Chronic Water Quality Criteria; and UMTR = Uranium Mining Tailings Reclamation. "Background Values" are provisional 90th percentile values taken from Hanford Site Background: Part 3, Groundwater (DOE/RL-96-91, Decisional Draft)

Table 8-1. Constituents Summary for 100-FR-3 Operable Unit (Page 2 of 2)

Table 8-2. Constituents in 100-F Area Wells that Exceed Standards

Constituents (Groundwater Standard)	Well Number	Maximum Concentration	Distance Inland (ft)	Remarks/Comments/Discussion
Chromium (50 $\mu\text{g/L}$)	199-F5-46	196	1,280	Isolated occurrence, no obvious source. Highly variable concentrations.
Gross Alpha (15 pCi/L)	199-F8-1 199-F8-3	206 18	3,200 3,820	Activity probably related to uranium.
Gross Beta (50 pCi/L)	199-F5-1 199-F8-1	56 98	600 3,200	In F5-1, associated with strontium-90 from liquid waste disposal trench. In F8-1, possibly related to fuel storage basin sludge disposed to trench south of reactor building.
Manganese (50 $\mu\text{g/L}$)	199-F5-43B	232	120	Common in Hanford sediments.
Nitrate (45,000 $\mu\text{g/L}$)	199-F5-4 199-F5-45 199-F5-46 199-F5-47 199-F5-48 199-F7-1 199-F7-2 199-F7-3 199-F8-1 199-F8-2 199-F8-3 199-F8-4	91,192 79,240 57,106 107,571 84,995 95,176 57,548 108,457 115,539 100,488 88,09 93,848	2,410 1,780 1,280 2,660 2,150 5,450 2,740 4,850 3,200 3,020 3,820 2,850	Widespread, multiple sources.
Strontium-90 (8 pCi/L)	199-F5-1 199-F5-3 199-F5-46	24 136 9	600 650 1,280	Source for F5-1 and F5-3 is effluent disposed to liquid waste disposal trench; F5-46 is isolated occurrence.
Trichloroethene (5 $\mu\text{g/L}$)	199-F7-1 699-77-36	24 26	5,450 (tbd)	Source is west of 100-F Area.
Tritium (20,000 pCi/L)	199-F8-3	111,000	3,820	Possible source is fuel storage basin effluent disposed to liquid waste trench near reactor.
Uranium (44 $\mu\text{g/L}$)	199-F8-1	257	3,200	Possible source is fuel storage basin sludge disposed to liquid waste trench near reactor

Table 8-3. 100-FR-1 Source Operable Unit High-Priority Waste Sites

Waste Site Group	Waste Site Name	Physical Waste Site Description	Former Waste Site Use	Contaminants of Potential Concern ¹
Process Effluent Trench	116-F-1 Lewis Canal	Unlined Trench 914m x 12m x 3 m deep	Received liquid waste from F Reactor and 190-F building and decontamination wastes from 189-F building	arsenic, cadmium, Co-60, Cs-137, Eu-152, Eu-154, K-40, lead, Ra-226, Th-228, U-238, zinc
Process Effluent Trench	116-F-2 Basin Overflow Trench (107-F)	Unlined Trench (three trenches connected together) - overflow trench 180 m x 39 m x 5 m EM overpass ditch 116 m x 12 m x 5 m diversion ditch 123 m x 12 m x 5 m	Received overflow from 116-F-14 retention basin and F Reactor	cadmium, chromium, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Ir-192, K-40, Pu-239/240, Ra-226, Th-228, zinc
Fuel Storage Basin Trench	116-F-3 Fuel Storage Basin Trench (105-F)	Unlined Trench 30 m x 6.1 m x 2.4 m deep	Received cooling water effluent and sludge from the F Reactor storage basin	chromium, Co-60, Cs-137, Eu-152, Eu-154, K-40, lead, mercury, PCB, Ra-226, Th-228, U-235, zinc, barium
Process Effluent Trench	116-F-6 Liquid Waste Disposal Trench (1608-F)	Unlined Trench 91 m x 30.5 m x 3.1 m deep	Received diverted cooling water effluent during reactor maintenance outages	chromium, Co-60, Cs-137, Eu-152, Eu-154, K-40, Pu-239/240, Ra-226, Th-228, U-238, zinc
116-F-9 Process Effluent Trench	116-F-9 PNL Animal Waste Leach Trench	Unlined Trench (two trenches connected together) - long trench 122 m x 5 m x 3 m deep short section - 30 m x 5 m x 3 m deep	Contaminated wash/waste water from animal pens, containing strontium-90 and plutonium-239	chlordane, Co-70, Cs-137, Eu-152, K-40, Ra-226, silver, Sr-90, Th-228, zinc
French Drain	116-F-10 dummy Decontamination French Drain (105-F)	1 m diameter x 2 m deep	Received spent nitric acid and rinse water from the decontamination of fuel element spacers at F Reactor	Co-60, Cs-137, Eu-152, Eu-154, Eu-155
Retention Basin	116-F-14 Retention Basin (107-F)	Reinforced rectangular concrete retention basin 415 m x 110.2 m x 7 m deep	Received cooling water effluent from F Reactor and reactor building drains	cadmium, chromium, Co-60, Cs-137, Cs-134, Eu-152, Eu-154, Eu-155, K-40, Ni-63, Pu-239/240, Ra-226, Sr-90, Th-228, U-238, zinc
French Drain	108-F French Drain	0.76 diameter x 1.8 m deep	Received condensate from hoods inside the 108-F biology laboratory	Am-241, chromium, copper, Cs-137, Eu-152, K-40, lead, PCB, Pu-238, Pu-239/240, Ra-226, selenium, Th-228, zinc

Am-241 = ²⁴¹Americium
 Cs-134 = ¹³⁴Cesium
 Eu-152 = ¹⁵²Europium
 Eu-155 = ¹⁵⁵Europium
 K-40 = ⁴⁰Potassium
 PCB = polychlorinated biphenyl
 Pu-239/240 = ^{239/240}Plutonium
 Sr-90 = ⁹⁰Strontium
 U-235 = ²³⁵Uranium

Co-60 = ⁶⁰Cobalt
 Cs-137 = ¹³⁷Cesium
 Eu-154 = ¹⁵⁴Europium
 Ir-192 = ¹⁹²Iridium
 Ni-63 = ⁶³Nickel
 Pu-238 = ²³⁸Plutonium
 Ra-226 = ²²⁶Radium
 Th-228 = ²²⁸Thorium
 U-238 = ²³⁸Uranium

¹The contaminants of potential concern were identified from the Qualitative Risk Assessment

Table 8-4. 100-FR-2 Source Operable Unit High-Priority Waste Sites

Waste Site Number/Name	Former Waste Site Use	Physical Waste Site Description	¹ Contaminants of Potential Concern
118-F-1 Primary Burial Ground	Received irradiated reactor equipment and other radioactive and nonradioactive solid waste.	Three unlined trenches and a pit in an area 183 x 152 x 6.1 m (600 x 500 x 20 ft) deep.	² ¹⁴ C, ¹³⁷ Cs, ⁶⁰ Co, ¹⁵² Eu, ¹⁵⁴ Eu, ³ H, ⁶³ Ni, ⁹⁰ Sr, cadmium, lead, mercury, organics ⁽³⁾
118-F-2 Solid Waste Burial Ground	Eight trenches received irradiated reactor equipment and other radioactive and nonradioactive solid waste. One trench received pipes with wooden lids containing animal carcasses and liquid waste.	Nine unlined trenches in an area 112 x 99 x 6.1 m (368 x 326 x 20 ft) deep.	⁶⁰ Co
118-F-3 Minor Construction Burial Ground	Received irradiated equipment from 105-F Reactor, primarily vertical safety rods and step plugs during the Ball 3X conversion.	Irregularly shaped, unlined burial ground in an area 53 x 15 x 4.6 m (175 x 50 x 15 ft) deep.	⁶⁰ Co
118-F-4 Burial Ground	Received radioactive silica gel waste from the 115-F building.	Unlined pit 3 x 3 x 3 m (10 x 10 x 10 ft) deep.	¹⁴ C, ³ H
118-F-5 Burial Ground (PNL Sawdust Pit)	Received radioactively contaminated sawdust and animal waste in boxes and drums.	Unlined trench 152 x 46 x 4.6 m (500 x 150 x 15 ft) deep.	⁶⁰ Co, ^{239/240} Pu, ⁹⁰ Sr
118-F-6 PNL Solid Waste Burial Ground	Received biological waste from animal research studies. Contains two rail tank cars that were used for incineration of animal carcasses.	Unlined trench 177 x 109 x 6.1 m (581 x 358 x 20 ft) deep.	^{239/240} Pu, ⁹⁰ Sr
118-F-9 Burial Ground (PNL Rad Site)	Received miscellaneous radioactively contaminated solid waste from the Experimental Animal Farm (EAF).	Two unlined trenches in an area 30 x 4.6 x 3 m (100 x 15 x 10 ft) deep.	Unknown
126-F-1 Powerhouse Ash Pit	Contains coal ash and soil that is radioactively contaminated due to leakage from the reactor effluent lines.	Irregular area approximately 335 x 145 x 6.1 m (1100 x 475 x 20 ft) deep.	⁽²⁾ ¹³⁷ Cs, ¹⁵² Eu, ^{239/240} Pu, chromium
PNL Parallel Pits	Received radioactive and nonradioactive solid waste from the EAF.	Two parallel burial trenches in an area 80 x 55 x 2.4 m (262 x 180 x 8 ft) deep. Each trench is 23 x 6.1 x 2.4 m (75 x 20 x 8 ft) deep.	Unknown

¹The contaminants of potential concern were identified from the qualitative risk assessment.

¹⁴ C	=	Carbon-14	³ H	=	Hydrogen-3 (Tritium)
¹³⁷ Cs	=	Cesium-137	⁶³ Ni	=	Nickel-63
⁶⁰ Co	=	Cobalt-60	^{239/240} Pu	=	Plutonium-239/240
¹⁵² Eu	=	Europium-152	⁹⁰ Sr	=	Strontium-90
¹⁵⁴ Eu	=	Europium-154			

²List of contaminants obtained from waste-site group description in the 100 Area Source Operable Unit Focused Feasibility Study.

³Five percent of burial ground volume is assumed to consist of organics, but no specific chemical constituent has been identified.

Table 8-5. Hydrogeologic Units Monitored by 100-F Area Wells

Well	Screened Interval Elevation; meters/(ft)	Hydrogeologic Unit	Average Ground- water Elevation meters/(ft)
F5-43A	113.5-107.4 m (372.2-352.2 ft)	Hanford formation	112.4m/(368.7ft)
F5-43B	75.6 - 72.5 m (247.9 - 237.9 ft)	Ringold Formation, overbank/paleosol, upper mud	112.4 m/(368.5 ft)

Notes:

1. Groundwater elevations averaged from quarterly steel tape measurements conducted from 1-1-94 to 8-30-95.
2. Screened intervals from unpublished Westinghouse Hanford Company geologic well summaries.
3. Survey elevations from ICF Kaiser Hanford, 1992.

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μS/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
Wells representative of conditions at or near the water table:											
199-F5-43A	120	368.72	6.2	365.9	372.1	18	187	66	164	230	4
199-F5-44	130	368.31	7.0	365.3	372.3	15	200	66	172	238	4
199-F5-42	230	368.48	5.0	366.4	371.4	14	206	68	186	254	4
199-F1-2	350	369.43	5.3	366.9	372.2	16	480	20	470	490	6
199-F5-6	480	368.82	3.8	367.3	371.1	15	427	466	310	776	8
199-F5-1	600	368.65	4.9	366.8	371.7	16	226	133	195	328	7
199-F5-3	650	369.32	1.6	369.1	370.6	10	371	5	368	373	2
199-F6-1	1,150	367.80	3.1	366.5	369.6	15	224	56	201	257	3
199-F5-46	1,280	368.82	2.4	367.8	370.2	14	589	97	527	624	4
199-F5-45	1,780	369.04	1.9	368.3	370.2	15	611	166	555	721	5
699-84-35A	1,800	373.43	0.8	372.9	373.7	3	414	260	284	544	2
199-F5-48	2,150	369.64	1.6	368.9	370.5	14	605	328	450	778	5
199-F5-4	2,410	369.53	1.1	368.9	370.0	13	813	60	780	840	4
199-F5-47	2,660	370.03	1.1	369.6	370.7	15	876	102	836	938	4
199-F7-2	2,740	370.99	0.7	370.7	371.4	15	651	14	644	658	4
199-F8-4	2,850	367.06	0.8	366.7	367.5	14	676	71	631	702	3
199-F8-2	3,020	370.32	0.7	370.0	370.7	11	868	67	831	898	4
199-F8-1	3,200	370.50	0.7	370.2	370.9	12	770	6	767	773	2
699-83-36	3,700	377.12	0.2	377.0	377.2	5					
199-F8-3	3,820	371.35	0.6	371.2	371.8	14	1,150	279	953	1,232	4
199-F7-3	4,850	372.65	0.3	372.5	372.9	12	818	128	747	875	5
199-F7-1	5,450	370.61	0.3	370.5	370.7	12	709	14	702	716	4

Table 8-6. Water Level and Specific Conductance in 100-F Area Wells (Page 1 of 2)

Table 8-6. Water Level and Specific Conductance in 100-F Area Wells (Page 2 of 2)

Well Number	Distance Inland (ft)	Water Level Elevation (ft)					Specific Conductance (μ S/cm)				
		Average	Range	Minimum	Maximum	No.	Average	Range	Minimum	Maximum	No.
699-77-36	7,600	375.52	0.2	375.4	375.6	14	563	20	553	573	2
<i>Wells with open intervals significantly below the water table:</i>											
199-F5-43B	120	368.54	5.3	366.1	371.4	25	523	0	523	523	1
Notes: Wells are listed in order of increasing distance from the river shoreline, as defined by low river stage. Data are representative of conditions between January 1, 1994 and August 30, 1995. Data source: HEIS.											

Table 8-7. Aquifer Test and Drawdown Test Results for 100-F Area Wells

Well	Hydraulic Conductivity cm/sec	Hydraulic Conductivity ft/day
F1-2	0.042	120
F5-42	0.028	80
F5-43A	0.044	125
F5-44	0.019	55
F5-45	0.011	30
F5-46	0.079	225
F5-47	0.035	100
F5-48	0.023	65
F6-1	0.024	70
F7-3	0.049	140
F8-3	0.009	205
F8-4	0.012	35

Notes;

1. All wells screened in Hanford formation.
2. Data from 100-FR-3 LFI report (DOE-RL, 1994d).

Table 8-8. Physical Properties for Aquifer Sediments in the 100-F Area

Well Number/ Depth Interval m (ft)	HEIS Sample Number	Specific Gravity g/cm ³	Bulk Density gm/cm ³	Moisture Content %	K _v Saturated cm/sec	Depth-to- Water m (ft)	Sediment Description
199-F8-3 1.37-1.52 m (4.5-5.0 ft)	B07502	2.80	2.05	4.3	0.026	7.74 m (25.38 ft)	Silty, sandy GRAVEL
199-F8-3 5.18-5.49 m (17-18 ft)	B07503	2.69	2.13	10.0	0.044	7.74 m (25.38 ft)	Slightly silty, sandy GRAVEL
199-F8-3 7.16-7.62 m (23.5-25 ft)	B07504	2.74	2.08	3.3	0.00022	7.74 m (25.38 ft)	Silty sandy GRAVEL
199-F5-48 3.35-3.50 m (11.0-11.5 ft)	B074Z8	2.73	2.00	2.9	0.010	13.59 m (44.60 ft)	Slightly silty, sandy GRAVEL
199-F5-48 7.93-8.08 m (26-26.5 ft)	B074Z9	2.68	2.00	8.6	0.00011	13.59 m (44.60 ft)	Gravelly, silty SAND
199-F5-48 11.73-11.89 m (38.5-39 ft)	B07500	2.72	2.12	3.4	0.00010	13.59 m (44.60 ft)	Silty sandy GRAVEL
199-F5-48 15.55-15.85 m (51-52 ft)	B07501	2.73	2.25	5.44	0.0017	13.59 m (44.60 ft)	Sandy GRAVEL
199-F5-43B 2.59-2.90 m (8.5-9.5 ft)	B07507	2.72	2.55	1.4	0.0031	7.1 m (23.17 ft)	Slightly silty, sandy GRAVEL
199-F5-43B 5.24-5.40 m (17.2-17.7 ft)	B07508	2.71	2.25	5.4	0.0013	7.1 m (23.17 ft)	Gravelly SAND
199-F5-43B 7.01-7.16 m (23-23.5 ft)	B07509	2.72	2.00	3.2	0.090	7.1 m (23.17 ft)	Slightly silty, sandy GRAVEL
199-F5-43B 9.3-9.6 m (30.5-31.5 ft)	B07510	2.72	2.29	7.21	0.0010	7.1 m (23.17 ft)	Sandy GRAVEL
199-F5-43B 21.65-21.95 m (71-72 ft)	B07512	2.66	1.58	27.7	0.000096	7.1 m (23.17 ft)	Silty SAND

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